Development of Innovative Steel Grades and Their Applications in Automotive Structures

Jonathan Powers
AK Steel Corporation
AK Steel’s Commitment to Innovation
AK Steel Announces Expansion of New NEXMET™ Advanced High Strength Steel

WEST CHESTER, OH, April 21, 2017--AK Steel (NYSE: AKS) said today that demonstration samples of new NEXMET™ 1000 and 1200 Advanced High Strength Steel have now been delivered to multiple automotive customers for evaluation. This milestone was made possible with the recently completed upgrades to the company’s Dearborn Works galvanizing line.

First announced in August 2016, the AK Steel NEXMET family of steel products enables automotive companies to design and manufacture lighter-weight vehicles that are capable of meeting increasingly stringent emissions regulations and passenger safety requirements.

While AK Steel’s NEXMET 440EX product is intended for use in surface-critical exposed auto
Upgrade Completed

- Fall 2016
- Additional control of thermal profile
- Additional control of furnace atmosphere
- Option to bypass zinc pot (bare)
### NEXMET™ 1000 and 1200 Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Yield Strength, MPa</th>
<th>Tensile Strength, MPa</th>
<th>Total Elongation, %</th>
<th>Hole Expansion Ratio, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEXMET™ 1000</td>
<td>730</td>
<td>1000</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>NEXMET™ 1200</td>
<td>1100</td>
<td>1210</td>
<td>15</td>
<td>30</td>
</tr>
</tbody>
</table>

**Production Data:**
- Tensile data by ASTM E8, 50 mm gage.
- HER by conical punch, 12% die clearance.

**Grade Families reproduced from:**
World Auto Steel Advanced High-Strength Steels Application Guide
Version 5.0, May 2014.
NEXMET™ 1000 and 1200 Microstructures
NEXMET™ 1000 and 1200 Strain Hardening

Mill produced material
NEXMET™ 1000 and 1200 Potential Applications

- Bare (CR) or Galvanized (GI)
- 1-2 mm thick
- <1320 mm wide
- Non-exposed applications
• Resistance spot weld properties for bare NEXMET™
• Acceptable current range, >2 kA
• Properties consistent with expectations for given base metal strengths
NEXMET™ 1000 and 1200 Other Characterization

- High strain rate – In Progress
- Corrosion – No issues
- Fatigue – In testing queue
Stamping Validation with T-Shaped Panel

**Tensile Strength (MPa) vs Draw Depth (mm)**

- **NEXMET™ 1200**
- **NEXMET™ 1000**

<table>
<thead>
<tr>
<th>Draw Depth (mm)</th>
<th>NEXMET™ 1000</th>
<th>NEXMET™ 1200</th>
<th>Dual Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>12.87</td>
<td>12.00</td>
<td>12.00</td>
</tr>
<tr>
<td>1000</td>
<td>15.85</td>
<td>10.70</td>
<td>10.70</td>
</tr>
<tr>
<td>1200</td>
<td>14.50</td>
<td></td>
<td>14.00</td>
</tr>
</tbody>
</table>
Stamping Validation with Hole Expansion

NEXMET™ 1200

NEXMET™ 1000

Tensile Strength (MPa) vs HER (%)
NEXMET™ 1000 NEXMET™ 1200 vs. DP980

- NEXMET™ 1000 1.55mm
- NEXMET™ 1200 1.55mm
- DP980 1.4 mm

Diagram showing comparison of strain values between NEXMET™ 1000, NEXMET™ 1200, and DP980 steels.
NEXMET™ 1000 and 1200 Springback Prediction

NEXMET™ 1000

NEXMET™ 1200
NEXMET™ 1000 and 1200 OEM Collaboration

- Plant Trials: Mar. 2015 - Mar. 2017
- Customer Trials: Apr. 2017 - Apr. 2018
Application 1: Optimize Body Side Structure

TARGETS

- Reduce mass
- Maintain roof crush performance
- Maintain side impact performance

* Public domain models courtesy of George Washington University
* Fully validated and correlated crash models
Application 1: Baseline Design

Mass: 16.75 kg

- **B-pillar Inner**: 1.0 mm
- **A-pillar Upper**: 1.4 mm
- **A-pillar Lower**: 1.4 mm
- **Rocker**: 1.4 mm
- **B-pillar Upper**: 2.1 mm
- **B-pillar Lower**: 1.2 mm
- **B-pillar Reinforcement**: 2.6 mm
- **Roof Rail**: 2.3 mm

Mass: 16.75 kg
Material and gage optimization was conducted to minimize mass.

Utilizing LS-Dyna & VisualDOC design optimization software:

- Side impact survival space of the baseline model is ‘Acceptable > 50 mm’, which correlates well with the IIHS physical test result.
- Roof crush strength-to-weight ratio of 3.783 of the baseline model correlates well with the IIHS physical test result of 3.78.

<table>
<thead>
<tr>
<th>Iterations</th>
<th>Side Impact Driver Side Survival Space</th>
<th>% Improvement from Baseline</th>
<th>Roof Crush Strength-to-Weight Ratio</th>
<th>% Improvement from Baseline</th>
<th>Mass (kg)</th>
<th>% Mass Reduction from Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>54.2</td>
<td>-</td>
<td>3.783</td>
<td>-</td>
<td>16.75</td>
<td>-</td>
</tr>
<tr>
<td>Optimized</td>
<td>70.4</td>
<td>30</td>
<td>3.809</td>
<td>0.68</td>
<td>12.04</td>
<td>28.1</td>
</tr>
</tbody>
</table>
Application 1: Optimized Design

Mass: 16.75 $\rightarrow$ 12.04 kg (28.1%)

Roof Rail: 2.3 $\rightarrow$ 1.5 mm
A-pillar Upper: 1.4 $\rightarrow$ 1.0 mm
A-pillar Lower: 1.4 $\rightarrow$ 1.0 mm
Rocker: 1.4 $\rightarrow$ 1.0 mm
B-pillar Upper: 2.1 $\rightarrow$ 1.2 mm
B-pillar Lower: 1.2 $\rightarrow$ 1.0 mm
B-pillar Reinf: 2.6 $\rightarrow$ 1.5 mm
B-pillar Inner: 1.0 $\rightarrow$ 1.2 mm

NEXMET™ 1000
NEXMET™ 1200
Application 2: Improved Deflector Assembly

<table>
<thead>
<tr>
<th>Part</th>
<th>Baseline</th>
<th></th>
<th>AK Steel</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade</td>
<td>Thick mm</td>
<td>Mass Kg</td>
<td>Grade</td>
</tr>
<tr>
<td>Deflector Assembly</td>
<td>DP 500</td>
<td>1.5</td>
<td>1.77</td>
<td>NEXMET™ 1200</td>
</tr>
</tbody>
</table>
Application 3: Light-Weight Front Lower Control

- Front Lower Control Arm (FLCA) component gage was reduced to minimize mass while keeping the permanent sets and the buckling load capacities of the baseline material.
- Permanent sets (Dx and Dy) were measured at ball joint after loading (Fx = Fy = 30 kN) and then unloading.
- Buckling load capacities (LCx and LCy) were also measured with loading (Fx = Fy = 40 kN).
- Both loading cases have the same constraints at two bushings.
- Abaqus FEA solver was used.
## Application 3: Front Lower Control Arm Results

<table>
<thead>
<tr>
<th>Iterations</th>
<th>Permanent set after Unloading @ BJ, Dx (mm)</th>
<th>Permanent set after Unloading @ BJ, Dy (mm)</th>
<th>Buckling Load Capacity @ BJ LCx (kN)</th>
<th>Buckling Load Capacity @ BJ LCy (kN)</th>
<th>Mass (kg) (One side)</th>
<th>% Mass Reduction from Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1.737</td>
<td>0.02834</td>
<td>32.578</td>
<td>36.413</td>
<td>2.911</td>
<td>-</td>
</tr>
<tr>
<td>NEXMET™ 1000</td>
<td>0.610</td>
<td>0.02864</td>
<td>&gt; 40.000</td>
<td>&gt; 40.000</td>
<td>2.868</td>
<td>1.5</td>
</tr>
<tr>
<td>NEXMET™ 1200</td>
<td>0.131</td>
<td>0.02857</td>
<td>&gt; 40.000</td>
<td>36.253</td>
<td>2.336</td>
<td>19.8</td>
</tr>
</tbody>
</table>
Applications of NEXMET™ 1000 and 1200 Grades

• Energy absorbing parts
• Parts needing additional formability
• High strength parts
• Potential part consolidation
• Mass reduction
NEXMET™ 440 EX

- Exposed Surface Quality
- Improved Dent Resistance
- Material Commercially Available

<table>
<thead>
<tr>
<th>Grade</th>
<th>YS, MPa</th>
<th>UTS, MPa</th>
<th>TE, %</th>
<th>BHI, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEXMET™ 440 EX</td>
<td>300</td>
<td>475</td>
<td>33</td>
<td>55</td>
</tr>
</tbody>
</table>
NEXMET™ 440 Applications

- NEXMET440EX Replacement of BH240
  - Similar performance for Dent/Ding.

Current Applications:
- 2011 Suzuki MR Wagon (Front Door Outer)
- 2014 Suzuki Hustler (Rear Door Outer)
- 2011 Suzuki D-Max (Hood Outer) (Thailand)
**NEXMET™ 440EX – Stamping Feasibility**

Full Sized Truck Fender
- Down gauge with NEXMET™ 440EX at 0.6 mm
- Performs better than BH 250 with 0.77 mm

NEXMET™ 440EX at 0.6 mm
- YS = 290 MPa
- TS = 475.8 MPa

BH 250 0.77 mm
- YS = 254 MPa
- TS = 370 MPa
Advanced High-Strength Steel (AHSS) Strategy

The graph illustrates the relationship between tensile strength and total elongation for different types of steel. The axes are labeled as follows:

- **Tensile Strength (ksi)**: This axis ranges from 0 to 250 ksi (kilo-pound per square inch).
- **Total Elongation (%)**: This axis ranges from 0 to 60%.

The graph shows the following types of steel:

- IF
- IF+HS
- Mild
- TRIP
- BH
- C+Mn+
- DP, CP
- HSLA, FB
- MS
- MnB+HF

The graph is used to compare the performance of these steels in terms of strength and ductility.
Advanced High-Strength Steel (AHSS) Strategy
Advanced High-Strength Steel (AHSS) Strategy
Advanced High-Strength Steel (AHSS) Strategy
Advanced High-Strength Steel (AHSS) Strategy

![Diagram showing the relationship between Tensile Strength (ksi) and Total Elongation (%). Various types of steels are labeled, including IF, IF+HS, Mild, TRIP, BI, CR+Mn, DF, CP, HSLA, FB, MS, MnB+HF, and NanoSteel®. The diagram illustrates the tensile strength range and the elongation percentage for each type of steel, highlighting the unique properties and applications of AHSS.]
Advanced High-Strength Steel (AHSS) Strategy

[Graph showing the tensile strength of different steel types, with a focus on mill trials.]
Advanced High-Strength Steel (AHSS) Strategy
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NEXMET™