ADVANCES IN HIGH STRENGTH STEELS FOR AUTOMOTIVE APPLICATIONS

Shrikant P. Bhat
Automotive Product Applications
ArcelorMittal Global R&D – East Chicago
- Material Choice in Automobiles

- Sheet Steel and the Automobile – General Introduction

- Fundamentals of Sheet Steel Metallurgy

- Product Characteristics and Application Trends
  - Hot Rolled Products
  - Cold Rolled Products
  - Coated Products
  - Hot Stamping

- Q&A
Steel – Material of Choice for Modern Living

• “Most Large Metal Structures are made of Carbon Steel – the World’s Most Useful Structural Material”
  – Kennedy Space Center website

• Integral Material for modern buildings, medicine, homeland security, food packaging, transportation and infrastructure.

• In today’s cars, Steel makes up about 62% weight
  - Steel is the Backbone of the entire vehicle
  (Protect occupants, Provide positive driving experience, React to road loads, Provide comfort, and attachment points to other components of the vehicle)
Automobile Weight Trend - VW

Year 2000: 800 kg
Year 1974: 778 kg
Increased safety needs and legislative requirements are the main reasons for the weight increase.

- **Comfort**: 15%
- **Quality**: 22%
- **Legislative requirements**: 8%
- **Safety**: 30%
- **Interior**: 25%

Weight increase:
- Ca. +10 kg p.a.
- Ca. +20 kg p.a.
Sheet Steel and the Automobile
Sheet Steel and the Automobile

Materials
- Conventional HSS
- UHHS
- Mild Steel

Design
- Safety
- Environment
- Customer Satisfaction
- Cost
- Light Weight
- Performance

Manufacturing

Tensile Stress (MPa)

Elongation (%)
SHEET STEEL AND THE AUTOMOBILE

Dent resistant  High strength  Ultra-high strength

Forming Grade
Automotive Sheet Steels

- Low Strength Steels (<270MPa)
- High Strength Steels
- Ultra High Strength Steels (>700MPa)

- Conventional HSS
- AHSS

Elongation (%) vs. Tensile Strength (MPa)
Fundamentals of Sheet Steel Metallurgy
Strengthening Mechanisms

- Work Hardening (Dislocation Strengthening)
- Solid Solution Strengthening
- Grain Refinement
- Precipitation Strengthening
- Phase Transformations

Strength/Ductility in Steel obtained by a combination of strengthening mechanisms
Processing of HiTen Steels
Time-Temperature-Transformation (TTT) Diagram

Legend
- Yellow: Austenite
- Martensite
- Ferrite
- Bainite

Microstructure

Legend
- Yellow: Austenite
- Martensite
- Ferrite
- Bainite
Sheet Steel Microstructures

- Ferrite (F)
- Martensite (M)
- Dual Phase (F + M)
- TRIP (F + B/M + RA)
# Strengthening Mechanisms in Sheet Steels - Summary

<table>
<thead>
<tr>
<th>Tensile Strength, MPa</th>
<th>Carbon Level</th>
<th>Solid Solution Hardening</th>
<th>Grain Refinement</th>
<th>Precipitation Hardening</th>
<th>Phase Transformation</th>
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<tbody>
<tr>
<td>270</td>
<td>Low</td>
<td>C</td>
<td>√</td>
<td></td>
<td>√</td>
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<tr>
<td>340</td>
<td>ULC - L</td>
<td>C, Mn, P</td>
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<tr>
<td>440</td>
<td>ULC - L</td>
<td>C, Mn, Si</td>
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<td>Nb, Ti, V</td>
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<tr>
<td>600</td>
<td>Low - Medium</td>
<td>C, Mn, Si</td>
<td>√</td>
<td>Nb, Ti, V, Mo</td>
<td>√</td>
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<tr>
<td>800</td>
<td>Low-Medium</td>
<td>C, Mn, Si</td>
<td>√</td>
<td>Nb, Ti, V, Mo</td>
<td>√</td>
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<tr>
<td>1000 DP</td>
<td>Low - Medium</td>
<td>C, Mn, Si, Mo</td>
<td>√</td>
<td>Nb, Ti, V, Mo</td>
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<tr>
<td>900 – 1500 M</td>
<td>Medium - High</td>
<td>C, Mn, Si</td>
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<td>√</td>
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</table>
Facilities for High Strength Steels

- **Soak**: 600-700°C for 18-36 hrs
- **Slow heating**
- **Slow cooling**

- **Soak**: >720°C for 3-4 min
- **Rapid cooling**: 500-1000 °C/s
- **Overage**: 200-400°C
- **Cooling**: 5-10°C/sec

**Continuous Annealing**

18. Welding Coils
19. Alkaline Cleaning
20. Anneal
21. Fast Cool
22. Water Quench
23. Pickling
24. Overage Furnace
25. Fast Cooling Furnace

**Coating**

Temperature (°C) 4-6 minutes

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Formability of Sheet Steels
Stress – Strain Curves as Surrogates
PRODUCT CHARACTERISTICS
HOT ROLLED STEELS

ENGINEERING STRESS - STRAIN CURVES
HR GRADES

HSLA 250
HSLA 350
HSLA 550
HSLA 590TS
HSLA 700
PRODUCT CHARACTERISTICS
GALVANNEALED STEELS

ENGINEERING STRESS - STRAIN CURVES
GA STEEL GRADES

ENGINEERING STRESS, MP

ENGINEERING STRAIN, %
TYPICAL STRESS STRAIN CURVES FOR 590 MPa FAMILY OF STEELS

Engineering Strain, %

Engineering Stress, MPa

- GA 590TRIP
- GA 590 DU
- GA 590

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Typical Hot Stamping Process Steps

- **First step**: heating of the blanks in furnace and rapid transfer to the press (5 to 7 seconds)
- **Second step**: rapid stamping (at 600°C-800°C) in the austenitic state
- **Third step**: quenching between the tools (> 30°C/sec)

Tools:
- Tools: 20°C < T < 200°C

Typical hot-stamping lines
Example Parts made with Usibor 1500P

Applications:

- A-pillar Usibor
- Bumper beam Usibor
- Fuel Tank Guard
- Door beam
- B-pillar Usibor
- A-pillar Usibor

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Main Properties After Hot Stamping

- No spring-back
- Complex geometries
- Very high Strength (1500 MPa)

Hot-stamped “Boron steels”

Properties in-use
TS = 1400-1600 MPa
YS = 1000-1200 MPa
E% = 6-8 %
SHEET STEEL APPLICATION TRENDS
2007 North American Light Vehicle Steel Content for Body, Bumper and Closures
(Extracted from the Ducker 2007 Report)

9,341 Million Pounds of Content for 9.9 Million Vehicles

Foreign Domestics
- Segmented by Type of Steel -

- Bake Hard 385 8.9%
- MHSS (340) 472 11.0%
- CHSS (440) 646 15.0%
- AHSS (590-980) 787 18.3%
- UHSS (Over 980) 63 1.5%
- Low Strength (270) 1,952 45.3%
- Low Strength (270) Includes wheels

4,305 Million Pounds of Content for 5.394 Million Vehicles

GM, Ford and DCX
- Segmented by Type of Steel -

- Bake Hard 576 6.2%
- UHSS (Over 980) 203 2.2%
- AHSS (590-980) 644 6.9%
- CHSS (440) 1,122 12.0%
- MHSS (340) 1,562 16.7%
- Low Strength (270) 5,234 56.0%

9,341 Million Pounds of Content for 9.9 Million Vehicles
There is a significant difference between the percent of AHSS in vehicles using a body on frame type architecture versus vehicles using a unibody type architecture.

**2007 Body and Closure Steel Content by Type**

- **Total Body on Frame**
  - HSS: 34.7%
  - Advanced HSS: 5.8%
  - Mild Steel: 59.5%
  - Total: 976 Pounds

- **Total Unibody**
  - Advanced HSS: 12.4%
  - Mild Steel: 51.5%
  - Total: 763 Pounds

- **Total**
  - Advanced HSS*: 9.4%
  - Mild Steel: 55.0%
  - Total: 842 Pounds

*AHSS is 73.6 pounds of Dual Phase, 5.8 pounds of martensitic, boron, complex phase, recovery annealed steels and TRIP steel not including door intrusion or bumper beams*
2007 North American Light Vehicle Flat Rolled AHSS and UHSS Steel Content

Dual Phase Steels

- DP 980: 17%
- DP 780: 8%
- DP 500/600 Including 590R: 75%

Total: 665,000 Tons

Other Steel Grades

- Recovery Annealed TRIP and CP Steels: 52,000 Tons (28.2%)
- Martensitic Steels: 57,200 Tons (31.1%)
- Boron Steels: 75,000 tons (40.7%)

Total: 184,200 Tons
Predicted Growth of AHSS Usage - VW

Share of body weight in percent

**Projected average**

- **Ultra high strength**: 5 - 10%
- **Extra high strength**: 30 - 35%
- **High strength**: 35 - 40%
- **Mild**: 20 - 25%

**2015**

**Example mid-size car**

- High strength: 62
- Extra high strength: 36
- Ultra high strength: 30
- Mild: 24

**2003**

Source: TAP, automaker experts
AHSS usage to grow significantly

- Advance of Japanese OEMs in AHSS implementation
- AHSS Growth currently limited by transformation constraints
- Future Emerging markets needs calculated as if required AHSS were available.
Automotive Sheet Steels

<table>
<thead>
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<th>Elongation (%)</th>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>600</td>
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<tr>
<td>20</td>
<td>1200</td>
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<tr>
<td>30</td>
<td>1600</td>
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<tr>
<td>60</td>
<td></td>
</tr>
<tr>
<td>70</td>
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</tbody>
</table>

- **Low Strength Steels (<270MPa)**
- **Ultra High Strength Steels (>700MPa)**
- **High Strength Steels**
  - IF
  - IF-HS
  - Mild
  - ISO
  - BH
  - CMn
  - HSLA
  - DP
  - TRIP
  - MART

- **Conventional HSS**
- **AHSS**
- **TWIP**
- **USIBOR**

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QUESTIONS?

THANK YOU