Development of New Auto Steels and Application Technology

Nov. 21, 2013
POSCO Automotive Steel
Automotive Steels in POSCO

Sales in 2003~2012

- Sales in 2003 to 2012 has been increasing by CAGR of 11.7%.
- In 2012, total sales is 7.3 million tons including 62% overseas sales.
- High strength steel and AHSS are occupied with 44.7% of total sales.

Sales Mix in 2012

- Coated Product : 33.5%
- HSS+AHSS : 44.7%
Development of AHSS

- Conventional AHSS
  - DP, TRIP, CP, Mart, HPF
  - TSxEl < 25,000 MPa·%

- eXtra-AHSS (X-AHSS)
  - Giga duplex, Light weight steel
  - 25,000 < TSxEl < 50,000 MPa·%

- Ultra-AHSS (U-AHSS)
  - TWIP steel
  - TSxEl > 50,000 MPa·%

GA 490DP for Door Outer – World First Production (2005)

- Requirement: Surface quality, Dent resistance, Stiffness
- Replacement of 340BH steel by 490DP steel
  → Weight reduction 7%, improvement of dent resistance 53%

![Graph showing weight reduction and improvement of dent resistance](graph.png)

Applications

- Door outer, 0.7t GA 490DP
- Removal of Body panel reinforcement sealer

![Application images](application_images.png)
GA 590DP for Closure Parts

- Trial for hood outer: 21% weight reduction (0.7t 340BH → 0.55t 590DP)
- Trial for fender at Japanese automobile company shows good formability

Applications

- Small Sedan, Hood outer
  GA 590DP (0.55t)

- Japanese Car, Fender
  GA 590DP (0.55t)

[ Hood outer using GA 590DP of 0.55mm thickness ]
Super Formable IF HSS

IF HSS (E/ES-class)
- High elongation and excellent r-value
  → suitable for outer parts requiring strength & formability

<table>
<thead>
<tr>
<th>Grade</th>
<th>Class</th>
<th>YS (MPa)</th>
<th>TS (MPa)</th>
<th>EI (%)</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>340E</td>
<td>CR/EG</td>
<td>≥167</td>
<td>≥340</td>
<td>≥32</td>
<td>1.75</td>
</tr>
<tr>
<td></td>
<td>GI/GA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>340ES</td>
<td>CR/EG</td>
<td>≥180</td>
<td>≥340</td>
<td>≥35</td>
<td>2.25</td>
</tr>
<tr>
<td></td>
<td>GI/GA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Application
- 340E Steel on Korean OEM’s SIDE OTR PNL
  → World’s first commercial application
  → Weight Reduction 7% (EDDQ 0.7t → 0.65t)
  → We have 340ES for better than 340E

[ One Piece Side Outer (domestic company) ]
**CR/GI/GA 980DP with good bendability**

- Reduce the strength difference between phases → **Improvement of bendability**
- Low $C_{eq}$ decreasing welding nugget hardness → **Increase of ductility ratio**

<table>
<thead>
<tr>
<th>Bending direction</th>
<th>Spec. (R/t)</th>
<th>Bendability (GA980DP: 2.0t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R/t</td>
<td>0.5R</td>
</tr>
<tr>
<td>L</td>
<td>≤ 2.5</td>
<td>1.5</td>
</tr>
<tr>
<td>C</td>
<td>≤ 2.5</td>
<td>1.3</td>
</tr>
</tbody>
</table>

**Applications**

- **Back side bracket (CR 980DP)**
- **Cross section of spot welded GA980DP steel**
- **Floor panel tunnel (GI 980DP)**
1180CP Steel

GA 1180CP for Reinforcement Parts

**Requirement**
- High YR
- Bendability
- Spot weldability
- Zn coatability

**Developing Target**
- YS ≥ 850 MPa,
  TS ≥ 1180 MPa
- Bending radius ≤ 3 x thickness
- Low $C_{eq}$ and Si content

- Suppress ferrite and promote bainite transformation → High YR, excellent bending property

**Applications**
- Material Change (EG 590TRIP → GA 1180CP steel)
  → Achieve 33% of weight reduction
  → First commercial production in the world

[ Microstructure ]

[ Rocker Outer (Domestic company) ]
GI 1470Mart

GI 1470Mart for Reinforcement Parts

- Safety regulation for frontal small overlap crash test: 25% offset collision introduced by IIHS
  - So, rocker or side sill becomes more and more important where anti-corrosion is also significant
- Commercialization of the world 1st GI 1470 Martensitic steel

< Mechanical properties >

<table>
<thead>
<tr>
<th>YS (MPa)</th>
<th>TS (MPa)</th>
<th>T-EI (%)</th>
<th>YR</th>
<th>Bendability$^{(1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 1050</td>
<td>≥ 1470</td>
<td>≥ 5</td>
<td>&gt; 0.71</td>
<td>≤ 6</td>
</tr>
</tbody>
</table>

$^{(1)}$ Bendability = Min. corner radius / Thickness

Applications

- Rocker Outer
- Bumper Beam

→ First commercial production in the world

* cf. www.iihs.org
TWIP Steels (U-AHSS)

**Characteristics**

- High Mn austenitic steel work-hardened by twinning
- High energy absorption by excellent strain hardening rate
- Very high strength-ductility combination (1000MPa, 65%)
  - **Commercialization**: Cold rolled product, 2011~ (POSCO, World First)
- Developing high YS TWIP steels (900, 1100, 1300, 1500, 1700 grades)

**Applications**

- High TS, High El: Bumper, member etc.
  - **Commercialized Bumper of European Vehicle**
    - (28% weight reduction, 22% cost saving)
- High HER, High El: Wheel, Low arm etc
  - Low arm: 540MPa FB (4 Ops)
    - 980MPa TWIP (2 Ops)

**Examples**

- Bumper Beam, Commercialized product ('12)
- Wheel, Chassis with TWIP steel
- Part development of BIW (body in white) and Chassis

- The red colored parts are made from TWIP steel through collaboration with customers.
- Recently, the number of chassis application is increasing as the advantage becomes apparent with TWIP steel.
To meet the customers needs for high YS TWIP steels, POSCO developed three grades, 900_HY, 1000_HY and 1200_HY, which is utilized work hardening by skin pass rolling.
Medium Mn TRIP steel (X-AHSS)

**Characteristics**

- Medium Mn addition → increase of austenite stability
- **High TS strength, yield ratio and elongation with a large amount of austenite**
- Duplex microstructure of ultra-fine retained austenite and ferrite

**< Mechanical Properties >**

<table>
<thead>
<tr>
<th></th>
<th>YS (MPa)</th>
<th>TS (MPa)</th>
<th>El (%)</th>
<th>TSxEl (MPa%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>980 DP</td>
<td>780</td>
<td>1040</td>
<td>11</td>
<td>11440</td>
</tr>
<tr>
<td>980 Duplex</td>
<td>937</td>
<td>1033</td>
<td>28</td>
<td>28924</td>
</tr>
</tbody>
</table>

**< Microstructure >**

- **X-AHSS grade!!**
- (TS X El ≥ 25,000MPa%)
  
- CR 980 Duplex
  
- Austenite
  
- Ferrite

[Image of mechanical properties table and microstructure diagram]
POSCO Application Technology

New Forming Technology

Lightweight Solutions for Chassis

POSCO Lightweight Body Concept

Electric Power Train
New Forming Technology

- Tailored Hot Press Forming
  - Implementation: Multi-strength HPF, TWB HPF to enhance the ductility in specific area

[ Conventional Design ]

- HSS 380Y
- HSS 590
- HSS 590

- Laser welding
- Multi-strength HPF
  - HPF1470 (1.5GPa)
  - HPF1470 (0.6GPa)

(TWB Blank)

(TWB Blank)

CHSP340Y (0.6GPa)
New Forming Technology

- **POSCO’s own FE Program (Shape-MDRF)**
  - Reduction of Calculation Time with High Accuracy

- **Unique Solution for the Prevention of Distortion**
  - Incremental Counter Forming Method

**PosRollForm (Multi-Directional Roll Forming)**

- **Concept**: Producing Variable Sectional Profile using Linear & Rotational Movement of Stands

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**POSCO Application Tech.**

- **New Forming Technology**

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**[Conventional Product]** (Uniform Section)  
**[PosRollForm Product]** (Variable Section)

- Side Sill
- Floor Cross Member

**[PBC-EV PosRollForm Part]**

**[PosRollForm Test Facility]**
Lightweight Solution for Chassis

**Torsion Beam Axle**

- Removing reinforcement (bracket) for a lightweight torsion beam → Design Optimization and Advanced Manufacturing by Hydroforming Technology
- New Concept: Bended and Expanded Beam for Structural Performance

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**Project on Torsion Beam Axle Development**

- **Original Beam**
- Weight Down + Bracket Removing
- **Design Optimization**
- Weld Durability Analysis
- **Proto Beam – Hydro forming**
- Durability Test
- **Optimized H/F beam**
- **FB780 One-piece Beam**
Lightweight Solution for Chassis

**Styled Steel Wheel**

- Lightweighting by Shape Optimization and Advanced Manufacturing Technology
- New Concept: High Stiffness Rim (TWIP980 steel + Hydroforming)
  
  TWB Disk (HB780 steel - 3.6t / 3.2t)
POSCO Body Concept: PBC-EV

**Objectives**

- To integrate POSCO's steel products & application tech. to provide Cost Efficient Steel Solutions for electric vehicle to our customers
- To identify Requirements of New Steel Grades and New Opportunities for Steel

**Dimensions**

Overall Length 4320mm, Wheelbase 2750mm, Width 1830mm, Height 1550mm

**Styling & Packages**

- CFD Based Styling for Optimal Aerodynamic Design
- High Roof Package for Maximizing Passenger/Battery Spaces
- Detachable Rear Battery Package

[ Computational Fluid Dynamic (CFD) simulation ]

\[ Cd = 0.285 \]
Design Results

- Weight Reduction: 26.4%
- Performance: [Crash] 5 Star & Good Safety Rating, No Battery Damage
  [Stiffness] Static Bending/Torsion > 15000, Dynamic Bending/Torsion = 51.2/47.4Hz
- Steel Grades

Body Weight: 218 kg
Weight Reduction: 26.4%

* Body Weight: Without Bumper Impact Beam
Manufacturing Process

Manufacturing Process (As % of BIW Structure Mass)

- Drawing, 45.6%
- MS-HPF, 6.2%
- HPF, 2.0%
- MD-RF, 5.5%
- HF, 2.3%
- Roll-Forming, 5.8%
- Warm Forming, 2.0%
- Etc., 0.5%
- Forming, 29.9%
- Roll Forming + Forming = 41.2 % (Including PosRollForm)

POSCO Body Concept : PBC-EV

POSCO Application Tech.
Demonstration

World 1st Body Concept for Electric Vehicle
By Steel Company

- Weldability Test
- Assembly

Process Design & Formability Analysis
Prototyping

POSCO Application Tech.

POSCO Body Concept: PBC-EV

Transition line
Ductile Zone
Hard
Weld-line
HPF1470
CHSP340Y
MD-RF
MD-RF

Process Optimization & Prototyping
1. Solution for RCAR Test
   - Effective Solution for RCAR Structural Tests

2. Extra Lightweight Model
   - Additional Lightweight by Structure Improvement and Increase of HPF Parts (HPF ratio in BIW: 8.2 → 17.1%)

3. High Torsional Stiffness Model
   - Torsional Stiffness Improvement: 50.0%↑ (17.2 → 25.8 kN/deg)
POSCO EPT Applications

High Performance and Reliability: PMSM EPT System with High Power Density & High Efficiency

- Compact [High Power Density]
- Light Weight [Key Factor for EV]
- Low Cost [Optimized Design]
- Easy Installation [Parts Integration]

Products

- 100kW EPT – PMSM, PCU
- 60kW EPT – PMSM, PCU

Applications to EV (Electric Vehicle)

- EV Conversion for EPT Test
  - Various Performance Evaluations
  - Road Driving Test
- Mid-size EV Buildup with Customer
- Small Size EV Development in Consortium

* PMSM: Permanent Magnet Synchronous Motor
100kW PMSM

**Major Specifications**
- Motor Type: Interior Permanent Magnet
- Max. Power: 100kW @ 5,600rpm/90sec
- Continuous Power: 60kW @ 0~12,000rpm
- Max. Torque: 320Nm/90sec
- Cooling: Water (65°C, 12ℓ/ min)
- Power Density: 1.6kW/kg

**Performance**

**T-N Curve**

- 60kW is available stably for whole speed range

**Efficiency Map**

* Avg. 95% efficiency in most frequent usable operating
** Avg. efficiency (UDDS LA4mode): 92%
Concluding Remarks

**POSCO has been developing new advanced materials and application technologies for vehicle lightweighting**

**POSCO develops new technologies, utilizing external as well as internal resources for customer value creation**