Coil-Applied Coating for Press-Hardening Steel

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1. Background on High Strength / Press Hardening Steels
2. Press Hardening Processes
3. Goal for an Inorganic Protective Coating
4. Data: Hot-Stamping, Corrosion, Welding, & Painting
5. Status
Hot Stamping Process
Coating Prevents High Temp. Scaling

Indirect process
- Cold stamping
- Heating
- Hot stamping

Direct process
- Heating
- Transfer
- Stamping + hardening
Boron Alloyed Steel for High Strength

Stamping Automotive Parts

Tensile strength and microstructure change during hot stamping.
<table>
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<tr>
<th>Coating Type</th>
<th>Usage/Advantage/Disadvantage</th>
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| Hot dipped aluminized steel (Al/Si-layer) | • Only for direct process (cracks if cold)  
  • Weldable without sand blasting  
  • Hard surface and abrasive  
  • Moderate corrosion protection |
| Hot dipped galvanized steel (Zn-layer) | • Cathodic corrosion protection  
  • Direct or indirect stamping process  
  • Diffusion of Zn into steel matrix  
  • Evaporation of & contamination with Zn  
  • Not weldable; sand blasting required |
| Hot dipped Zn/Ni-layer (90/10)      | • Cathodic corrosion protection  
  • Safety issues with Ni |
| Silane/Al-based inorganic coating   | • Not weldable; sand blasting required  
  • No corrosion protection |
Coating for High-Strength/PH Steel

Goal: Provide next generation of anti-scaling PH coating:

- Permanent coating (no sand blasting)
- Weldable
- E-Coatable
- Corrosion protection and paint adhesion after E-coating meets OEM expectations/standards

Severe scaling after 950°C, lab panel without coating

No scaling after 950°C, lab panel with coating

Uncoated Part
Technical Approach for Improved Coating

Protective System at 950°C

**Approach:** Develop an inorganic “paint-like” anti-scaling coating to protect press hardening steel during hot stamping at 950°C.

- Inorganic binder system necessary
  - Siloxane binder system for the coating
  - Pretreatment based on silicate/silane chemistry
- Al-flakes to build up oxygen barrier
- Pigmentation for better corrosion performance and spot welding

Heat resistant conducting pigments, in combination with Al-flakes

Conductive pigments with good electrical and thermal conductivity, low melting point, high boiling point, moderate hardness.
Coating Before Hot Stamping

SEM Appearance (Coated, not Heated)

Relatively smooth surface at low magnification

Al flakes visible at high magnification
Coating Before/After Hot Stamping

GDOES Characterization

Before Heating

After heating to 900°C
- Fe migrates into coating
- O increases (Al\textrightarrow Al_2O_3)
Thermal Stability of the Coating

TGA Analysis: RT → 1000 °C (under N₂)

Solvent Loss

Very little weight loss, <4%
Coating Appearance After Hot Stamping

Hot Stamped Part

- No scaling observed when coated to 2-3 μm
- Coating adheres through heating and stamping

Prototype Die and Part
Before Hot Stamping

Salt Spray
• Non-formed parts exposed for 24 hrs develop light to moderate rust.
• The extent is related to surface roughness (lower is better) and DFT (higher is better).

Humidity (100%/100°F)
• Non-formed blanks or treated coil survives 168 hrs without rust.

After Hot Stamping
• Stamped parts will develop rust when exposed to the conditions above.
• Rusting is comparable to aluminized steel from side-by-side trials.
Hot Stamped Appearance
Comparable to Aluminized PH Steel

Control

Aluminized, 7 min, 930°C

PH Coating, 850°C

PH Coating, 3 min. 950°C

PH Coating, 11 min. 950°C

PH Coating, 900°C
Corrosion After Hot Stamping

168 Hr Humidity

Control

Aluminized, 7 min, 930°C

PH Coated, 850°C

PH Coated, 3 min, 950°C

PH Coated, 11 min, 950°C
Welding Study on 22MnB5 Steel

Coil-Applied Pretreatment + PH Coating

PH Coating Thickness (2.2 μm) + Pretreatment (50 mg Si/m²)
(115 Spots according to SEP 1220-1)

Front Side of Panels

Back Side of Panels

Shows PH coated panel (both sides coated) welded to bare HDG panel
Body-in-White Processing

Cleaning & Pretreatment

Cleaning

• Surface before 900˚C exposure has “water-break” after rinsing.
• Surface after 900˚C exposure is “water-break free” after rinsing.
• Hot-stamped parts will behave like “clean” surfaces in a BiW process.

Pretreatment

• No reaction or interference with standard Zn-phosphate bath
• No reaction or interference with new 2-step Zn/Zr process
• No reaction or interference with the new zirconium oxide processes
Body-in-White Processing

Cleaning & Zinc Phos: No Reaction

Treated Surface after 900 °C heating

No Zn-Phosphate Crystals
Body-in-White Processing

Cleaning & Zr Oxide: No Reaction

Treated Surface after 900 °C heating

No Zirconium Oxide Layer
Cleaning

- Coil coated PH surface is etched less in the alkaline cleaner than aluminized steel. Less build up of Al in cleaner bath.

Pretreatment

- Zn phosphating of uncoated PH steel after shot blasting is difficult.
- Zn phosphating of aluminized steel requires special conditions.
- Al ion rapidly builds up in a Zn phos bath with aluminized steel.
- Cryolite, Na$_3$[AlF$_6$], must be precipitated out to avoid bath poisoning (high cost, labor, waste production).
**E-Coating After Hot Stamping**

- Panels subjected to 900 °C exposure come out of E-coating with good appearance and with good adhesion.
- Normal 20 μm E-coat layer is deposited under standard conditions.

**Corrosion Testing**

- After 900 °C exposure + pretreatment + E-coat the PH coating performs equivalent to aluminized steel (testing continues)
  - ASTM D3359 Cross Hatch Adhesion
  - ASTM B-117 Neutral Salt Spray
  - SAE J400 Stone Chipping
Status: Coil-Applied Coating for PH Steel

- First full-scale manufacture was successful.
- First full-scale coil coating successful (Precoat).
- Coil coated steel now being tested by several steel companies.

Results of hot stamping
- Parts successfully hot-stamped by several parties.
- Parts formed equivalently to aluminized steel standard
- Heating time to PMT was less than aluminized (e.g. 3 vs. 7 min).

Results of E-Coating
- Parts successfully E-coated after all 3 standard BiW pretreatments
Next Steps: Coil-Applied Coating for PH Steel

- Continue BiW process studies.
  - Continue testing to various OEM corrosion/adhesion specs.
  - Optimize pretreat and coating formulas for corrosion performance.

- Continue welding studies.
  - Coated steel is weldable to bare steel/galvanized.
    - Optimum conditions and operational window to be clarified.
  - Coated steel hasn’t yet been welded to itself.
    - Optimize pretreatment coating weight and formulation.

- Verify compatibility with structural adhesives.

- Fine tuning of the formulation is expected following initial testing.