COATING TECHNOLOGIES

ZINC-BASED COATINGS: EFFICIENT & COST EFFECTIVE OPPORTUNITIES

19TH GALVANISING & COIL COATING CONFERENCE
SEPTEMBER 2014
ABU DUBAI
A Technology driven Group

Energy

Defence

Industry

Services
CMI FPE – Global Footprint
Various Types of Coating

- Zinc Coating
- Zinc Coating with Alloys
- Color Coating
- Chrome Plating
- Resin Coating
- Tinning
Zinc Coating
Why Coating and Why Zinc

- **Zn has the advantage of Cathodic protection**
  - Zn dissolves instead of Fe
  - Zn gives a sacrificial protection
  - Electrochemical effect in presence of Water
  - Zn has some capability of protection of Steel at distance
    - Ex: edges, scratches...
  - Corrosion products protect more or less the substrate
The various Process

Electro deposition
- Based on $\text{Zn}_2^+ + 2 \text{ e}^- \rightarrow \text{Zn}$
- Used for sheet but also bolts and fasteners
- Sheets must be annealed and Skin Passed before coating

Hot dip Coating
- Batch Galvanizing
  - The first process
  - Pickling, Fluxing, Galvanizing
  - Products after galvanized after fabrication
  - Advantage of no edge exposed
  - Still used (many small factories)

Continuous
- Various process from Fluxing to present design
How to Produce Zn Coatings

- **Vapor Deposition**
  - New process under development
  - Takes the benefits of the low Melting and boiling T of Zn

- **Spray coating**
  - Used on some big components
  - Use Zn powder

- **Matoplasty**
  - Consist in smashing Zn particles on the surface by glass balls

- **Sheradization**
  - Surfacial diffusion of Zn by heating

- **Zn rich Paints**
  - Chemical protection quite limited due to low conductivity
Metal Coating - Options

- Zinc And/Or Alloys
Why coating & Why Zn and/or alloys

- Zn corrodes quite slowly
- Zn corrosion depends on
  - SO2 concentration
  - Strong reduction of atmospheric corrosion thanks to reduction in SO2 pollution
  - Ph (Low Ph are bad)
  - Chlorides
    - due to high solubility of ZnCl2
- Zn is Cheap
- Al gives no sacrificial protection but increase corrosion resistance
  - Only barrier protection
  - Due to its passivation
- In case copper plating, Fe would be sacrificial to Cu
- Mg, added to Zn stabilize the Corrosion products
  - Barrier effect
Zincalume and Galfan® were developed to improve durability, especially in highly corrosive environments (marine severe. A low cracking behaviour was also targeted

- Galfan is Zn+ 5%Al + 100 to 200ppm of La+Ce
- Zincalume is 55%Al + 1.5% Si +Zn
- Galvalume is a registered trade mark of Zincalume

Zn+Mg coatings with different compositions still targeting better corrosion resistance

- Various coatings are under development
Why coating & Why Zn and/or alloys

- Al addition improves the corrosion resistance but reduce the sacrificial protection
• Hot Dip Coating
What is Hot Dip Coating

- **The Hot Dip Process**
  - Has been invented by the French J. Malouin in 1742
  - Developed in France by Stanislas Sorel in 1837-42
  - The 1st factory has been erected in Germany in 1847

- **2 Main routes**
  - Hot dipping of finished products
    - Limited surface quality
    - No risk of edge corrosion
    - Limited productivity
  - Hot dipping of semi-finished products
    - Highly technological

- **The Continuous Process**
  - Developed by the Polish engineer Sendzimir in 1933
  - Developed later in France and USA from 1936
  - Improved for automotive in Europe and Japan in the 80s
What is Hot Dip Coating

- **Principle**
  - Submerge a piece of Steel in a Liquid Metal
  - Reach a perfect Wetting to totally cover the surface
  - Adhesion and Coating Thickness are Key points

- **Adhesion needs**
  - Continuous Metal structure from Fe to Coating
  - The surface must be free of Oxide & Oil prior dipping
  - Fe and coating diffuse to each other

Typical Cross Section of a batch Zn Coating

![Typical Cross Section of a batch Zn Coating](image-url)
Coating selection is based on its corrosion resistance
But not only on flat panels
Edges (Fe exposed) are important

No. of Hours before 5% red rust

On an average, corrosion resistance by salt spray test is:
- HDG: 8-10 h/µm;
- Galfan®: 25 h/µm;
- Aluzinc®: 100 h/µm

Corrosion resistance of metallic coatings in salt spray test (edges protected)
[OCAS/S. Claessens/2003]
### The Different HDG Coatings

#### Various Hot Dip Coatings 4 to 20 µm:

<table>
<thead>
<tr>
<th>Coating</th>
<th>Cross cut</th>
<th>Bath</th>
<th>Microstructure</th>
<th>Intermetallic layer</th>
<th>Intermetallic layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot dip galvanized (HDG)</td>
<td>Zinc coating</td>
<td>Zn, ~0.2%Al</td>
<td>Zn monophase</td>
<td>(\text{Fe}_2\text{Al}_5)</td>
<td>Pb/Sb From 0.004 to 0.15%</td>
</tr>
<tr>
<td>Gi</td>
<td>Steel substrate</td>
<td>460°C</td>
<td></td>
<td>100 to 200 nm (thin)</td>
<td></td>
</tr>
<tr>
<td>Galfan®</td>
<td>Zn rich dendrites</td>
<td>Zn, ~5%Al, La</td>
<td>Zn rich dendrites and eutectic phase with lamellar</td>
<td>(\text{FeAl}_3)</td>
<td>No Pb allowed</td>
</tr>
<tr>
<td></td>
<td>Lamellar matrix</td>
<td>Ce (0.02%)</td>
<td>structure (Zn rich, Al enriched)</td>
<td>10 to 20 nm (very thin)</td>
<td></td>
</tr>
<tr>
<td>Galvalume®</td>
<td>Al rich dendrites</td>
<td>55%Al, 43.5%Zn</td>
<td>Al rich dendrites, Zn rich matrix and Si rich</td>
<td>(\text{AlZnFeSi})</td>
<td>No Pb allowed</td>
</tr>
<tr>
<td>GL</td>
<td>Si</td>
<td>1.5%Si, 600°C</td>
<td>particles</td>
<td>1 to 2 µm (thick)</td>
<td></td>
</tr>
<tr>
<td>Galvannealed</td>
<td>Zn rich phase</td>
<td>Zn</td>
<td>Multi phases with Fe content from 30 to 9%Fe</td>
<td>(\text{Fe}_{3}\text{Zn}\text{10})</td>
<td>Pb rarely accepted (automotive)</td>
</tr>
<tr>
<td>Ga</td>
<td>AlZnFeSi intermetallic</td>
<td>0.1 to 0.14%Al</td>
<td>Average Fe content 10-12%</td>
<td>(\text{FeZn}\text{7})</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>460°C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## HOT DIP COATINGS

Comparative study of 5 series of coatings

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Galvanized (Zn)</th>
<th>Galvannealed (Zn-Fe)</th>
<th>Galfan (Zn-5% Al)</th>
<th>Galvalume (55% Al-Zn)</th>
<th>Aluminized (Al-11% Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formability</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>2</td>
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<tr>
<td>Corrosion resistance (bare)</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>5</td>
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<tr>
<td>Sacrificial protection</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Corrosion resistance (formed)</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>2</td>
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<tr>
<td>Paint adhesion</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Corrosion resistance (painted)</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Weldability</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Thermal resistance / reflectivity</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

5 = best performances
1 = worst performances
Future

The New Coatings in HDG

The Zn- Al- Mg Case
• A change is expected due to the wish of increase in corrosion resistance
  – … or reduce coating for the same resistance
• From all the elements, Mg is the most promising
  – Corrosion products are more stable and play a protective role
• Various products are available on the market and some new one may be proposed
• The process is not expecting to change dramatically since melting T is quite similar
## Zn-Al-Mg Coatings

Many possible coatings, most being licensed

<table>
<thead>
<tr>
<th></th>
<th>% Al</th>
<th>% Mg</th>
<th>Others</th>
<th>Market</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magi Zn</td>
<td>1-1.5</td>
<td>1-1.5</td>
<td></td>
<td>Auto-Construction</td>
<td>Tata Corus</td>
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<tr>
<td>Magnelis</td>
<td>3</td>
<td>3</td>
<td></td>
<td>Auto-Construction</td>
<td>Arcelor</td>
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<tr>
<td>Super Dyma</td>
<td>11</td>
<td>3</td>
<td>0.2% Si</td>
<td>Auto-Construction</td>
<td>NSC</td>
</tr>
<tr>
<td>ZAM</td>
<td>6</td>
<td>3</td>
<td></td>
<td>Construction</td>
<td>Nisshin</td>
</tr>
<tr>
<td>Galfan + Mg</td>
<td>4.2-4.5</td>
<td>0.2-0.5</td>
<td></td>
<td>Construction</td>
<td>Nisshin but not In use</td>
</tr>
<tr>
<td>DymaZn</td>
<td>0.2</td>
<td>0.5</td>
<td></td>
<td>Construction</td>
<td>No patent</td>
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</tbody>
</table>
### Appearance of coatings

<table>
<thead>
<tr>
<th>GI (Zn-0.18%Al)</th>
<th>GF (Zn-4.5%Al-0.1%Mg)</th>
<th>ZAM (Zn-6%Al-3%Mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Porous &amp; Course" /></td>
<td><img src="image" alt="Porous" /></td>
<td><img src="image" alt="Granular &amp; Fine Corrosion Products" /></td>
</tr>
</tbody>
</table>

Appearance of corrosion products after 4 hours salt spray test (Coating weight: 90 g/m²)

Reference:
Coating comparison

Red rust occurrence after salt spray test

<table>
<thead>
<tr>
<th>Coating Type</th>
<th>Graphical Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZAM®</td>
<td>![ZAM® Image]</td>
</tr>
<tr>
<td>Galvanized</td>
<td>![Galvanized Image]</td>
</tr>
<tr>
<td>Zn-5%Al</td>
<td>![Zn-5%Al Image]</td>
</tr>
<tr>
<td>55%Al-Zn</td>
<td>![55%Al-Zn Image]</td>
</tr>
</tbody>
</table>

*2,500 Hours of Salt Spray (Coating Weight: .30 oz/ft² on one side)
• Special flux

• PMT for flux drying

• Lead free bath

• Zn – Al 5% bath

• Strip Entry at Bath 200 – 300 Deg C
ZINC COATING – WET FLUX LINE
GALFAN THRU’ DRY FLUX TECHNOLOGY

STRIP TEMP.
100°C – 120°C (max.)

STRIP TEMP.
200°C – 300°C

DRY FLUX TANK

SQUEEZE ROLL

DUNK ROLL
• Color Coating
Why Paint coating on Zn?

- **The Corrosion Resistance**
  - Increases the total coating thickness (becomes more difficult to scratch up to the steel)
  - Anti-corrosion treatment on the Zn surface (promoting adherence of the primer on Zn) and anti-corrosion primer
  - Very long life time (above 20 years in European regulation for buildings)

- **The Aesthetic Properties**
  - Colour, gloss
  - Smooth, structured, orange peel, embossed surface
  - Pearl effect, ...

- **Some Specific Properties**
  - UV resistance, chemical resistance, stain resistance, ...
  - Anti-bacterial coating, ...
  - Flexibility, ...
Cross section of Prepainted Steel

The different possible constituent layers in a coil coated sheet:

- Topcoat
- Primer
- Surface treatment
- Zinc coating
- Steel
- Zinc coating
- Surface treatment
- Reverse coating
Base Chromium

Substrate Galvanized/Galvalume

Coating Thickness 1.5 to 2.5 micron

Color Dye = 10 - 15 %

Concentration 100%

Application Method Chemcoater

PMT 85 - 95 Degree C
## ECONOMIC COMPARISON FOR VARIOUS COATINGS

<table>
<thead>
<tr>
<th>Operational Parameter</th>
<th>GI</th>
<th>GL</th>
<th>Zn-Mg</th>
<th>GF Regular</th>
<th>GF Dry Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Fuel Gas</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Wiping Gas</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Dross</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Zn/Alloy Cost</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Life of Coating</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

5 = **best** performances  
1 = **worst** performances
THANK YOU FOR YOUR ATTENTION

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