Eckart Functional Effect Pigments

Zinc flake based anti corrosion paints with reduced heavy metal content.

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Marketing & Technical Service

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Agenda

- History of Zinc flake pigments.
- Production process of Zinc flake pigments
- Properties of Zinc flakes in comparison to Zinc dust
- Mode of operation
- Products
- DIN ISO 12944 update
- Examples (heavy duty, dip coat, shop primer)
- Economic efficiency & Sustainability
- Outlook
- Sammery
History of the Zinc flakes

The development goes back to the 70’s.

Project Motivation:

- Maximum anti-corrosion properties at a very thin film thickness
- Especially for metallic components exposed to extreme mechanical forces.

First applications:

- Screws, Clips and Chassis components.
Production process of Zinc flakes

Zinc ingot (99.995%)

Melting process

Atomization process

Sieving process

Grinding process

Mineral spirit

Lubricant (Stearic acid)
Properties of Zinc flakes in comparison to Zinc dust

SEM Pictures

Zinc flake x 450
Average particle size: ca. 15 µm

Zinc dust x 700
Average particle size: ca. 3 µm
## Properties of Zinc flakes in comparison to Zinc dust

<table>
<thead>
<tr>
<th>Property</th>
<th>Zinc flake</th>
<th>Zinc dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle shape</td>
<td>Flaky</td>
<td>Spherical</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>40 / 1 (~ 350 nm thick)</td>
<td>1.5 / 1</td>
</tr>
<tr>
<td>Bulk density</td>
<td>~ 1.1 kg/l</td>
<td>~ 2.2 kg/l</td>
</tr>
<tr>
<td>Oil absorption value</td>
<td>~ 22</td>
<td>~ 6.5</td>
</tr>
<tr>
<td>Average particle size</td>
<td>~ 11-20 µm</td>
<td>~ 3 µm</td>
</tr>
<tr>
<td>Specific surface area</td>
<td>~ 1.2 m²/g</td>
<td>~ 0.25 - 0.5 m²/g</td>
</tr>
<tr>
<td>Binder uptake</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Zinc volume concentration</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>
Mode of operation

Protective mechanisms of pigments in primers

The morphology of Zinc flake pigments allows to combine the roles as Barrier as well as Galvanic protection, leading to superior anticorrosion performances.
Mode of operation

Galvanic effect

1) Electrochemical process

Direct contact zinc- iron
Iron electrochemically more precious than zinc

- Zinc sacrifices itself to protect iron
- Zinc starts to oxidize

2) Cementation (i.e. sealing zinc layer will be formed)

Zinc pigments oxidize

- Volume increase
- Pores are sealed (i.e. barrier protection)
Mode of operation

Galvanic effect

Sacrificial Corrosion / Cathodic Protection

- Zinc oxidizes first and protects Iron

Self-Healing:
Formation of Zinc corrosion products can seal the area and stop the corrosion process
Mode of operation

Passive Corrosion Protection

Lamellar pigments retard the movement of water through the coating

Extended path
Mode of operation

Zinc dust

- Active Cathodic Corrosion Protection: Yes
- Passive Corrosion Protection after Cementation: Yes
- Initial Passive Corrosion Protection: No (before Cementation)

Flake

- Active Cathodic Corrosion Protection: Yes
- Passive Corrosion Protection after Cementation: Yes
- Initial Passive Corrosion Protection: Yes (before Cementation)
Mode of Operation

Dosage: Identification of the percolation threshold

Requirements:

- The Zinc particles have to touch each other and the substrate.

Formation of percolation path

- Necessary filler content depends on size and geometry

Zinc dust

Percolation threshold at PVC min. 40%

Zinc flake

Percolation threshold at PVC min. 10%
Mode of Operation
Dosage: Identification of the percolation threshold

Statistics:

- Probability of forming a conductive network increases with increasing surface-to-volume ratio of the zinc particles at a given volume fraction of zinc particles.

\[
\frac{\text{Surface}}{\text{Volume}}_{\text{Zinc dust}} < \frac{\text{Surface}}{\text{Volume}}_{\text{Zinc Flake}}
\]

Zinc dust have contact points

Zinc flakes have flat contact areas

Optimum PVC-Range

- Zinc flake: 12-25%
- Zinc dust: 50-60%
Mode of Operation

Summary

**Metal Powder versus Flake**
- Higher contact area improves thin film performance

**Zinc Dust**
- Low contact area
- Low conductivity

**Zn Flake**
- Better Barrier
- Higher aspect ratio
- High contact area
- Galvanic protection maximized
## Zinc flake – Portfolio:

<table>
<thead>
<tr>
<th>Type:</th>
<th>FK</th>
<th>particle size D 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>STANDART® Zinc flake TV</td>
<td>100 %</td>
<td>50 µm</td>
</tr>
<tr>
<td>STANDART® Zinc flake GTT</td>
<td>100 %</td>
<td>13 µm</td>
</tr>
<tr>
<td>STANDART® Zinc flake G</td>
<td>100 %</td>
<td>9 µm</td>
</tr>
<tr>
<td>STANDART® Zinc flake AT</td>
<td>100 %</td>
<td>20 µm</td>
</tr>
<tr>
<td>STAPA® TE Zinc AT</td>
<td>90 %</td>
<td>17 µm</td>
</tr>
<tr>
<td>STAPA® TE Zinc GTT</td>
<td>90 %</td>
<td>13 µm</td>
</tr>
<tr>
<td>STAPA® Zinc 4</td>
<td>90 %</td>
<td>14 µm</td>
</tr>
<tr>
<td>STAPA® Zinc 8</td>
<td>90 %</td>
<td>11 µm</td>
</tr>
<tr>
<td>STAPA® 4 ZnAl7</td>
<td>91,5 %</td>
<td>14 µm</td>
</tr>
<tr>
<td>STAPA® 4 ZnSn 30</td>
<td>91,5 %</td>
<td>14 µm</td>
</tr>
<tr>
<td>STAPA® 4 ZnSn 15</td>
<td>91,5 %</td>
<td>14 µm</td>
</tr>
</tbody>
</table>
DIN ISO 12944 update

First test results of a Zinc flake 2 C Epoxy primer on low-alloy carbon steel (sand blasted SA 2 ½)

Dry film thickness ca. 60-70 µm

Before SST ac. ISO 9227

After 1700 h SST ac. ISO 9227
DIN ISO 12944 update

First test results of a Zinc flake 2 C Epoxy primer on low-alloy carbon steel (sand blasted SA 2 ½)

After 1700 h SST ac. ISO 9227

Dry film thickness ca. 60-70 µm

After mechanical cleaning

applying of a paint remove mass
Residence time 2 h

After 1700 h SST ac. ISO 9227
DIN ISO 12944 update

First test results of a Zinc flake 2 C Epoxy primer on low-alloy carbon steel (sand blasted SA 2 ½)

Dry film thickness ca. 60-70 µm

Before SST ac. ISO 9227

V1001 nach 1700h (Ritz gereinigt)

No corrosion creep!

After 1700 h SST ac. ISO 9227

After cleaning

V1001 nach 1700h (Ritz gereinigt)
### Grind formulation (Component A1)

<table>
<thead>
<tr>
<th>No.</th>
<th>Component</th>
<th>Amount</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Epilox L25-80 (Dichte 1,12 / FK 80%)</td>
<td>88</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Disperbyk 102</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>Heucophos ZCP</td>
<td>32</td>
<td>3.2</td>
</tr>
<tr>
<td>4</td>
<td>Lösemittel SA</td>
<td>43</td>
<td>4.3</td>
</tr>
<tr>
<td>5</td>
<td>Blanc fixe micro</td>
<td>118</td>
<td>11.8</td>
</tr>
<tr>
<td>6</td>
<td>Micro Talcum AT extra</td>
<td>146</td>
<td>14.6</td>
</tr>
<tr>
<td>7</td>
<td>Sylosiv A3</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>8</td>
<td>Garamite 1958</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>9</td>
<td>Lösemittel SA</td>
<td>45</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Add while stirring, dissolve 40 min at 3,0 m/sec (disc).

### Zinc flake pre mix (Component A2)

<table>
<thead>
<tr>
<th>No.</th>
<th>Component</th>
<th>Amount</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Epilox L25-80 (Dichte 1,12 / FK 80%)</td>
<td>43</td>
<td>4.3</td>
</tr>
<tr>
<td>2</td>
<td>Epilox AF 18-30 (Dichte 1,16 / FK 100%)</td>
<td>24</td>
<td>2.4</td>
</tr>
<tr>
<td>3</td>
<td>Disperbyk 102</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>4</td>
<td>MIBK</td>
<td>36</td>
<td>3.6</td>
</tr>
<tr>
<td>5</td>
<td>Stapa Zinc 4 (FK 90%)</td>
<td>245</td>
<td>24.5</td>
</tr>
</tbody>
</table>

Add while stirring, dissolve 20 min at 2,0 m/sec (disc).

Add one after another Pos. 6 to 8 under stirring and mix homogeneously.

### Component B (Hardener Component)

<table>
<thead>
<tr>
<th>No.</th>
<th>Component</th>
<th>Amount</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Epilox H 14-50 (FK = 100%)</td>
<td>65</td>
<td>6.5</td>
</tr>
<tr>
<td>2</td>
<td>Novares LA300</td>
<td>17</td>
<td>1.7</td>
</tr>
</tbody>
</table>

GESAMT

### Lack(ier)parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auslaufzeit DIN 4</td>
<td>28 s</td>
</tr>
<tr>
<td>Lackdichte</td>
<td>1,566 g/cm³</td>
</tr>
<tr>
<td>D3 Spindel (250 U/min)</td>
<td>nM cP</td>
</tr>
<tr>
<td>0</td>
<td>50% 222</td>
</tr>
<tr>
<td>80 min</td>
<td>58% 227</td>
</tr>
<tr>
<td>140 min</td>
<td>60% 238</td>
</tr>
</tbody>
</table>

Gänge

<table>
<thead>
<tr>
<th>Durchfluss</th>
<th>naß</th>
<th>trock.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2.0</td>
<td>250</td>
<td>70</td>
</tr>
</tbody>
</table>
Example Shop Primer:

- Shop Primer are thin & fast drying coatings, mostly for steel.

- In the end of the steel production the parts will be sand blasted. That process is necessary to remove oxide layers (layer of scale). After that the parts will be coated by a shop primer to prevent the steel of corrosion.

- In this condition the steel can be stored until the further processing.
Example Shop Primer:

Technical requirements

- Thickness of the dry film app. 20 µm
- Protect against corrosion for min. 6 month
- Drying time 3-5 min.
- No toxic fumes during welding processes
- No negative impact on the welding quality
- Good intercoat adhesion to the top coat.
Testing formulation:

### Example Shop Primer:

<table>
<thead>
<tr>
<th>Component</th>
<th>Formula</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2 C EP Zinc flake shop primer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Component A:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epikote 1001-X-75</td>
<td>9.6</td>
<td></td>
</tr>
<tr>
<td>Heucophos ZCP plus</td>
<td>3.7</td>
<td>- pre disperse –</td>
</tr>
<tr>
<td>Araldite GY 783</td>
<td>7.3</td>
<td>- add and stir homogeneously –</td>
</tr>
<tr>
<td>Solventnaphtha</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>MIBK</td>
<td>9.5</td>
<td></td>
</tr>
<tr>
<td>n-Butanol</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Byk 410</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Blanc fixe micro</td>
<td>13.7</td>
<td></td>
</tr>
<tr>
<td>Micro Talkum AT extra</td>
<td>16.9</td>
<td></td>
</tr>
<tr>
<td>Stapa zinc 4</td>
<td>28.5</td>
<td></td>
</tr>
<tr>
<td><strong>Component B:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aradur 115 (hardener)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Component B:**  

This paint is ready to use.

### Commercially available system

<table>
<thead>
<tr>
<th>Component A:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Toluene</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>n-Butanol</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Epico 1001X75</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Anti-terra U</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>BYK-052</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Byk-323</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Zinc dust</td>
<td>76.0</td>
<td></td>
</tr>
<tr>
<td>Xylene</td>
<td>4.15</td>
<td></td>
</tr>
<tr>
<td>Byk-410</td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>

**Component B:**  

This paint is ready to use.
Example Shop Primer:
Technical data of the formulations:

<table>
<thead>
<tr>
<th></th>
<th>2C EP Zinc flake</th>
<th>2C EP Zinc dust</th>
<th>1C Silikate Zinc dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (ready to use)</td>
<td>1,650 g/cm³</td>
<td>2,420 g/cm³</td>
<td>2,417 g/cm³</td>
</tr>
<tr>
<td>Solid (ready to use)</td>
<td>76,60%</td>
<td>77,60%</td>
<td>86,10%</td>
</tr>
<tr>
<td>VOC (ready to use)</td>
<td>390 g/l</td>
<td>540 g/l</td>
<td>416 g/l</td>
</tr>
<tr>
<td>Spreading rate (20µm df)</td>
<td>17,3 m²/kg</td>
<td>8,2 m²/kg</td>
<td>13,9 m²/kg</td>
</tr>
</tbody>
</table>
Example Shop Primer:
Rheological profile:
Example Shop Primer:

Test results after 10 days SST (DIN EN 23270)

Comparison of the zinc oxide formation

Zinc dust  Zinc flake
Example Shop Primer:

Test results after 10 days SST (DIN EN 23270)

1 mm Steel panel; roughness: ca. 30 µm
(Pretreatment: sand blasted)

2C EP Zinc dust  2C EP Zinc flake  1C Silikat Zinc dust
Example Shop Primer:

Test result after 10 days SST (DIN EN 23270)

5 mm Steel panel; roughness: ca. 80 µm
(Pretreatment: sand blasted)

2C EP Zinc dust
2C EP Zinc flake
1C Silicate Zinc dust
Adhesion and intercoat adhesion after 300h Salt spray test

**Example Shop Primer:**

<table>
<thead>
<tr>
<th></th>
<th>2C EP Zinc dust</th>
<th>2C EP Zinc flake</th>
<th>1C Silicate Zinc dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primer + 2C PU Top Coat</td>
<td>4.0 N/mm²</td>
<td>8.5 N/mm²</td>
<td>4.5 N/mm²</td>
</tr>
<tr>
<td>Primer</td>
<td>4.5 N/mm²</td>
<td>6.0 N/mm²</td>
<td>5.0 N/mm²</td>
</tr>
</tbody>
</table>


Example: Dip coat

Axle Carrier Mercedes E-Class-After 2000 hours of salt spraying test

Zink flake primer: 12-14 µm
Top coat: 8-10 µm
Example: Heavy Duty

Railway bridge in Immenstadt Germany after 20 years exposure

Coating System

- **Primer:**
  
  2 K Epoxy – Zinc flake ca. 60-100 µm dft.

- **Intermediate layer:**
  
  2 K Epoxy- iron- mica: 160- 200 µm dft.

- **Top Coat:**
  
  2 K PU ca. 50-80 µm dft.
Example: Heavy Duty

Railway bridge in Immenstadt Germany after 20 years exposure

Dirt can be easily removed mechanically

Cross cut after 20 years
Outlook

Development of a zinc flake 2 C epoxy waterborne system

The next test series are running with an iron mica intermediate layer.

Of course the panels of the current test series are prepared with a 2mm cut.
Cost effectiveness

The zinc price is subject to strong price fluctuations
Assumption:

- If the zinc dust primer will be replaced by a zinc flake primer, in a DIN ISO 12944 C 5 very long compliant coating system, than the savings potential, at todays zinc prices, would be around **15 - 20 %**
  (formulation and application- adjusted)

- Note: This calculation does not take extended renovation cycles into account.

Further coast saving potential!
Sustainability

Economic use of resources

Zinc dust demand

- The estimated zinc dust demand in the coating industry was between ca. 200,000 - 250,000 tons in 2014.

Theoretical adoption:

- If the zinc dust will be replaced by zinc flake in all relevant coating applications, the theoretical savings potential for the metal zinc would be between 120,000 to 150,000 tons per year.

Theoretical savings potential up to 60 %
The proof of concept is well known since many years, especially in the dip spin market.

- **Technical Advantages**
  - better intercoat adhesion
  - more flexible coating films
  - less heavy coating container (lower density of a zinc flake based primer)
  - very low white rust formation
  - very good anti-corrosion properties (two in one concept)

- **Economic & Sustainability Advantages**:
  - less VOC content (calculated on the coated area)
  - less heavy metal content!
  - At high metal prices more price flexible
Thank you for your Attention!

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