the 14th Nordic Corrosion Congress in Copenhagen

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Agenda

Functional coating and surface preparation

1. Surface preparation with sponges
2. Functional coating with composites
3. References
Surface preparation

New technology with sponges reinforced with silicium oxides and steel grit

1. Less dust
2. Worker safety and visibility
3. Chloride removal
4. Recycles up to 15 times
## Petrobras test of surface preparation methods

<table>
<thead>
<tr>
<th></th>
<th>UHP</th>
<th>Grit</th>
<th>Sponges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker safety</td>
<td>Poor</td>
<td>Good</td>
<td>Ideal</td>
</tr>
<tr>
<td>Surface quality</td>
<td>Poor</td>
<td>Ideal</td>
<td>Ideal</td>
</tr>
<tr>
<td>Lifetime before coating</td>
<td>Reasonable</td>
<td>Good</td>
<td>Ideal</td>
</tr>
<tr>
<td>Costs</td>
<td>Poor</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Productivity</td>
<td>Good</td>
<td>Ideal</td>
<td>Ideal</td>
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NASA test Feb, 2007

National Aeronautics and Space Administration did a big comparable test of the new generation of surface preparation methods. Following were tested:

• Plastic Blast Media.
• Hard Abrasive Steel Media.
• Sponge Blast Media
• Liquid Nitrogen.
• Mechanical Vacuum Cleaning.
• Portable Laser Coating Removal System.
Conclusion of NASA test

It can be concluded that based on the requirements set forth by the project stakeholders, the Sponge technology was the superior technology for the identified need. Sponge technology (as demonstrated) proved to be a low-dusting alternative that achieved adequate paint strip rates on carbon steel. Other benefits of Sponge Technology include the high recyclability of the media, ease of use, and the high levels of worker visibility.
Economic in use

Conventional Abrasive Blasting

Sponge Blasting

40% Lower Total Project Costs

Media Costs
Containment
Overblast & Rework
Handling Costs
Disposal Costs
Air Management
Functional coating

Composites reinforced with ceramics

1. High adhesion to the substrate
2. Low permeability
3. High resistance to erosion and wear
Composites for Metals
Engineered to Rebuild and Upgrade Metal Surfaces

- Severe Abrasion
- Corrosion / Erosion
- Chemical Attack
COMPOSITE: A Substance Composed of Two or More Materials in *Separate* Phases

**Matrix Phase**

**Reinforcement Phase**

**Fibers**
- Aramid
- Graphite
- Glass
- Nylon

**Particles**
- Ceramic
- Mineral
- Metals
- Quartz

**Polymers**
- Epoxy
- Phenolic
- Polyester
Why Do Metals Fail?

Primary Cause of Metal Failure:
Weak Surface Layer

- Fatigue
- Impact

- Abrasion
- Corrosion / Erosion
- Chemical Attack
- Cavitation

Structural Surface
Erosion

Corrosion
Rebuilding Protection
Why Do Coatings Fail?
Assuming Correct Surface Preparation and the Coating is Not Chemically Attacked -- Example: 2-Part Solvent Based Epoxy

At the Gel Point the Film Takes Final Form.
Solvent Remaining Leaves Microscopic Voids When it Evaporates

All Coatings Breathe. Voids at the Metal Surface Become Ideal Corrosion Cells

Most Metal Oxides Have a Larger Volume Than the Base Metal thus Creating an Expansive Force on the Coating When it Corrodes. If the Coating Cannot Resist the Expansive Force Created the Result is Underfilm Corrosion
Composite Technology

100% Solids, No Solvent, Vacuum Mfg.

**Goal - Eliminate Microscopic Voids Throughout Film**

Goal is to Get 100% Contact with the Surface

Real World is That a Film Break Will Eventually Occur

*No Underfilm Corrosion*

To Ensure Optimum Resistance to Underfilm Corrosion Material must have High **Tensile Adhesion**; High Flexural Strength & High Permeation Resistance
## Adhesion Test Results

### Danish Technological Institute (1990)
- ISO 4624 procedure
  - Composite 855: >207 kg/cm², >2940 psi

### Surftec A. S. Norway, Mark Adhesion tester (1997)
- Unique equipment that eliminates any shear loading
  - Composite 982: 370 kg/cm², 5260 psi
  - Composite S2: 396 kg/cm², 5630 psi
  - Composite 855: 594 kg/cm², 8440 psi
    - "Highest adhesive strength they have ever measured"

### Sintef Norway – ISO 4624 Pull-Off Test (2000)
  - Composite S2: 251 kg/cm², 3568 psi
  - Composite 855: 295 kg/cm², 4206 psi
  - Composite 897: 265 kg/cm², 3771 psi
Standard Accelerated Corrosion Test
ASTM B 117 Salt Fog Test

Coated Test Panels

35°C (95°F) 5% Salt Water

- Test: Record Number of Hours Coating Protects Against Corrosion
Standard Accelerated Corrosion Test

ASTM B 117 Salt Fog Test
Comparative Salt Fog Results

6000 Hours - Complete Failure

C163-2
2-Part, Solvent Epoxy

A351
2-Part, 100% Solids Epoxy

20,000 Hours - Surface Stains Only

Composite
Scored Salt Fog Panels
Composites

10,000 hrs. (20,000 hrs.)

Composite One Coat (100% solids)
Composite Two Coats (100% solids)
Composite Two Coats (100% solids)

No Underfilm Corrosion, only surface stains.
Corrocell Test Cell
Tests Material Resistance to Both Liquid and Vapor Phase Exposure

Can Control and Test Variables:
1. Chemical
2. Temperature
3. Δ Temp.-"Cold Wall Effect"

Meets:
ASTM D 4398
NACE TM-01-74
ANSI/ASTM C 868
Corrocell Test in 10% Sulphuric Acid at 50C

B5811 Panel after 14 weeks *

Composite Panel after 14 weeks

* First Blisters recorded after 3 weeks
Corrocell Test Results

Demin. Water, 50°C (120°F)

Days to Blister Onset

- Composite S1
- Composite 855
- B. SG
- P. Ceramalloy CL+
- A 400
- A 351
- C 163-2
- T. Liner Series
- FP Epoxycoat Sprayable
Maersk Decompression Test – Force Technology, Denmark

Tests a coatings ability to withstand explosive decompression. Composites passed the test with no apparent change.
Trash Racks for Major New Dam

Trash Racks Provide Critical Protection for Turbines. The Protective Coating Must be Able to Protect Long Term Under extremely demanding Conditions. Composites was Chosen

Trash Racks During the Application of Composites

Inlet Section to Dam Where the Trash Racks Will be Installed
Wastewater Storage Tanks

Wastewater Storage Tanks Handled Alkali, Acids and Solvents. The Previous Coating System Did Not Provide Suitable Protection

Four Wastewater Storage Tanks Which Were Restored and Protected With ARC S2

Old Coal Tar Coating Failure
Wastewater Storage Tanks

Two Coats of Composites were spray applied at 375 microns (15 mils) per coat

View of one of the four completed tanks
Corrosion on Cover and Water Boxes of Heat Exchanger

Heat Exchanger Protected with Composites

End Cover of Water Box Coated With Composites
Heat Exchangers
Standardized Protection with Composites

Largest Chemical complex in Africa.

Heat exchangers exhibit extensive galvanic corrosion, even with zinc anodic protection.
The Replacement Cost of Zinc Anodes Alone Was $250,000 Per Year!!

After 5 Years of Service and Over 1500 Heat Exchangers, Composites Has Become the Standard “Workhorse” for Corrosion Protection Throughout the Plant
98% Sulfuric Acid (H2SO4) Storage Tanks

Corroded, Above Ground, 98% H₂SO₄ Tanks with Failed Epoxy Coating

New Tanks Coated With Composites Inside and Out
Fortum Rauhanlahti Power Plant at Jyväskylä Finland. Plant uses peat and wood as fuel. Chimney is 130m (426 ft.) high and 3.5m (11.5 ft.) diameter. Material is Corten B.
After only a few years in operation the chimney was discovered to be corroding at an unacceptable rate. Flue gases enter the chimney at 130°C (266°F) but condense on the cooler surfaces of the chimney wall.
Composites was applied to the lower 47m (154ft.) and the top 16m (52ft.) of the chimney. Inspections after 5 and 10 years in service have shown that the corrosion rate is now under control.
Atmospheric Corrosion Protection
Ceramic Reinforcements Eliminate Corrosion / Erosion

- Tolerances unchanged after 15 years in service. Original uncoated alloy lost 9 mm (3/8 inch) in first two years of operation.

- Tolerances remain virtually unchanged thus maintaining efficiency throughout the life of the pump.
Damaged by corrosion and erosion. Rebuilt with Composites. Extremely smooth and uniform surface improved lime powder flow.
Waste water screw damaged by erosion / corrosion. Edge strip welded on to rebuild, Composites to protect. After 5 years - perfect condition.
Main Water Pump - Nuclear Power Plant

Extreme Galvanic Corrosion, Suction Bell Fell Off!
New Pump Cost $175,000
Main Water Pump - Nuclear Power Plant

Solution: After Blasting, Rebuilt with 240kg of Composites. Results: After 10 years in Service, only 2% of surface needed touch up.
Cooling Water pump Asnæsværket, Denmark from power plant protected with Composites
After 8 years continuous operation. Result: In perfect condition.
Main Cooling Water pump Denmark with Composites
Sulzer Pumps upgraded with Composites
Burner bends rebuild with composites
Coal dust pipes reinforced with Composites
Vacuum Pumps
30% of New Part Cost, Longer Life, Saves Energy

Typical Corrosion/Erosion Damage to Vacuum Pump Rotor

Rebuilding with Composites
Cost - 30% of New Cast Iron Parts, Longer Life, Tolerances Maintained Thus Maximum Efficiency

Over 15 Years Proven Results in Industry

1995 SCEMM Award Given to Motola (Nash Partner, Sweden) for Saving the Paper Industry Electricity by Using Composites on Vacuum Pumps
Original Equipment Upgraded

Over 15 Years of Successful Performance Rebuilding Vacuum Pumps

Result:
1995 Nash Introduced XL Series - New Product Line - Cast Iron, Upgraded with Composites
Seawater cooling system pipes at a power plant, Denmark coated external and internal with composites.
Pipes in service since 2004 with zero failures
Seawater pumps subjected to cavitation and corrosion by seawater: lifetime: 5,500 Hrs (steel mill)
New wear ring has been installed, the inner diameter of the Stainless steel wear ring corresponds with the original level of the pump casing (+/- 25 mm in depth of the metal is disappeared due to cavitation).
View of the pump after completion. After 3 months of operation, an inspection was done. Even the glossy finish of the ceramic composite was not removed by the cavitation in combination with severe corrosion.
Fan Blade at Cement Plant

Savings After 7 1/2 Months $126,000

<table>
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<tr>
<th>Method</th>
<th>Months</th>
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<tr>
<td>New Fan -</td>
<td>2 to 4</td>
</tr>
<tr>
<td>Weld Overlay -</td>
<td>2</td>
</tr>
<tr>
<td>Composites</td>
<td>&gt;7 1/2</td>
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Fan Blade Previously Welded as Shown, Now Rebuilt Using Composites
Decanters reinforced with composites.

Longer lifetime and big savings in maintenance.
Danish sewage pump coated with Composites. More than 5 years lifetime. Large savings in wear and energy consumption.
Pump for swim baths coated with Composite materials. Longer lifetime and energy savings
Any Questions?
Thank You for Your Time!