Outline

- Waterborne Direct to Metal Coatings
- Developing Waterborne DTM Binders
- Formulating Corrosion Resistant Coatings
- Application
- Testing of DTM Coatings
Waterborne Direct to Metal Coatings

- Waterborne acrylic coatings are suitable for light duty metal applications

- Light duty is defined by the C1 – C2 categories of the ISO Corrosion standards, ISO 12944-2
  - Corrosion categories C1/C2 correspond to a very low to low atmospheric classification
  - Heated or unheated interior spaces where condensation may occur or exterior environments with low levels of pollution

- Industrial maintenance such as pipes, tanks, handrails, steel doors, and rail cars, etc.
Waterborne DTM Coatings

- Direct to metal (DTM) coatings provide advantages over multilayer systems in light duty applications by
  - Reducing the number of application steps
    - Minimal surface preparation and only one application step
  - Lowering raw material costs with only one coating layer
  - Eliminating the need for active pigments
- Waterborne acrylic coatings provide high gloss (>80 on a 60° meter), good appearance and corrosion resistance
Waterborne DTM Coatings

- Waterborne acrylic coatings provide several advantages over solventborne coatings
  - Better for health and safety with less impact on the environment
  - Easy clean up and thinning with water
  - Low odor, less toxic and flammable solvents
  - Fast drying (ambient conditions or forced dry) which allows for faster recoating times
- However, low temperature and high humidity must be avoided for application and optimal film formation
Developing Waterborne DTM Binders
Developing Waterborne DTM Binders

New development for waterborne DTM binders continue to improve resin performance at reduced VOC

- A DTM binder is expected to provide corrosion protection without the aid of an anti-corrosive pigment
  - Waterborne acrylic binders provide corrosion resistance primarily by forming a barrier
  - Good continuous film formation is critical
A proper choice of binder composition and chemistry is needed to improve barrier properties toward ingress of water and salt

- The polymer needs to be hydrophobic and minimize the use of ionic compounds to prevent water from entering the film

A proper design of particle morphology helps with tuning film formation properties while minimizing the use of solvents and plasticizers
Developing Waterborne DTM Binders

- Resins changes are screened for corrosion resistance

202h B C D E F G H I J K L

483h B C D E F G H I J K L

646h B C D E

834h B C D E
Developing Waterborne DTM Binders

Analytical techniques can be used to evaluate the films and predict corrosion performance

- Electrochemical Impedance Spectroscopy (EIS) follows the change in capacitance of a coating when submerged in water or an electrolyte to provide information on the barrier properties of the coating
  - If the impedance stays the same over time, the capacitance is constant and this suggests that the coating is resisting ingress of water and salt
  - If the impedance drops very fast, water can penetrate into all or part of the coating
Developing Waterborne DTM Binders

Microscopy characterization techniques enable following the changes in the structure of the coating while exposed to a corrosive environment.

- When coupled with Energy Dissipative X-ray spectroscopy (EDX), one can obtain information on how the coating evolves chemically during its service life.
  - EDX allows you to search for different elements like sodium and chlorine on the image while you are taking pictures with the electron beam, so you see a microscopic image and also get information about where each atom is located.
Formulating Corrosion Resistance Coatings
The corrosion protection provided by waterborne acrylic coatings is highly dependent on both the resin and the formulation of the coating.

Often attempting to drop-in or directly replace resins in waterborne formulations does not result in optimum performance.

Choosing the appropriate solvents, additives and pigments is necessary to optimize the performance of the coating.
Formulating Corrosion Resistant Coatings

- Solvent choice
  - Co-solvent packages need to be optimized for each binder system and are very formulation dependent
  - The level of solvent (or plasticizer) required for good coalescence is dependent on the binder
  - Film formation of the resin alone (or the final coating) may be evaluated with a drawdown on Leneta card, curing at room temperature or in a refrigerator
  - Properties like water resistance can be affected by the type of solvents
Solvent Choice

- Formula A contains hydrophilic solvents and Formula B contains a plasticizer and more hydrophobic solvents. (Degree of blistering rated according to ASTM D714)
Formulating Corrosion Resistant Coatings – Additives

- **Dispersant**
  - A very good dispersion of pigments is necessary to avoid agglomeration and resulting film defects that allow penetration of the film
  - Dispersant choice is critical to corrosion resistance (the more hydrophobic the better)
Formulating Corrosion Resistant Coatings – Additives

- **Defoamers**
  - Necessary to eliminate macro and microfoam to ensure good film formation
  - Type and level will affect corrosion resistance

- **Wetting agents**
  - More hydrophobic is better for corrosion resistance, if required

- **Thickeners**
  - Associative non-ionic thickeners like HEUR and HMPE types are preferred for better film formation and to minimize the effect on corrosion
Formulating Corrosion Resistant Coatings – Pigments

- Titanium Dioxide – TiO₂
  - The grade of TiO₂ or coating on the titanium dioxide can have a significant effect on the corrosion resistance

- Colorant
  - Dispersed pigments contain surfactants than can also adversely affect the corrosion resistance
  - Choose colorants recommended for industrial coatings
Films for testing can be prepared by spray application:

- **Conventional air atomized spray**
  - Viscosity of the coating must be reduced to less than 70 KU for atomization
  - The appearance and film formation of waterborne coatings depends heavily on the temperature and relative humidity conditions

- **Airless or air-assisted spray**
Films for testing can be prepared by drawdown:

- **Drawdown bars** (Bird bars, Doctor blades, Latex applicator)
  - Either the gap or the wet film thickness are specified
  - For a 1–4 mil gap, the wet film thickness is approximately 50% of the gap
  - The actual wet film thickness depends on the shape of the applicator, the viscosity, surface tension and wetting properties of the coating, and the speed of application
Films for testing can be prepared by drawdown:

- **Wire-wound rods**
  - Coating flows through the grooves between the wires
  - The wet film thickness of the coating is approximated by the wire size of the rod

- The dry film thickness is approximately equal to the wet film thickness multiplied by the volume solids

- Target dry film thickness for a DTM is ~ 2 mils in one coat.
After application, films are allowed to dry at room temperature:

- Extreme conditions (low temperatures and high humidity) can result in poor film formation that affects performance.

- Testing is generally completed in standard conditions: 25°C, 50% relative humidity.
  - Most testing is completed after 7 days of ambient cure.
  - 7 day testing may be accelerated by 1 day of ambient cure followed by 1 hour in a 50°C oven.
Testing of DTM Coatings
Testing of DTM Coatings

- Substrates for Direct to Metal coatings:
  - Cold Rolled Steel, cleaned, unpolished (polished)
  - Sandblasted Hot Rolled Steel
  - Cold Rolled Steel with an Iron Phosphate treatment with or without a sealer (chrome or non-chrome)

- Standard test panels provide a uniform substrate for testing that minimizes the variation of the steel
Testing of DTM Coatings

- Corrosion testing

- Continuous Salt Spray (Salt Fog), ASTM B117
  - 5% NaCl salt fog at 35°C
  - Most common and most widely accepted corrosion test, however it does not correlate well with field performance

- Panels taped and scribed prior to test
  - Scribe creep rated according to ASTM D1654
  - Field rust rated according to ASTM D610
Corrosion Testing

Salt Spray Testing (ASTM B117) on a white DTM formula with no anti-corrosive pigments: DFT 1.5-2.0 mils
Corrosion Testing

Salt Spray Testing (ASTM B117) on a white DTM formula with no anti-corrosive pigments: DFT 2.5-3.0 mils

Polished CRS  Unpolished CRS

63 hours SST  184 hours SST  244 hours SST  312 hours SST
Corrosion Testing

Other types of testing that have better correlation to field performance:

- Prohesion or Cyclic Salt Spray (Fog), ASTM G85-A5
  - 0.35% ammonium sulfate, 0.05% sodium chloride
  - Cyclic: 1 hour salt spray at 25°C, 1 hour dry at 35°C

- Combined testing – Cyclic Salt Fog/UV Exposure, ASTM D5894
  - One week Prohesion
  - Once week QUV: 4 hours UVA (340 nm)/4 hours condensation
Testing of DTM Coatings

- Adhesion Testing, ASTM D3359
  - Dry: Scribe the coating with an X-cut or cross cut, apply tape and pull
  - Wet: Scribe the coating, cover the scribe with a filter paper, saturate with water and cover with a watch glass, after 60 minutes blot the area dry, apply tape and pull
  - Rate from 0 – 5
    5 = no removal of coatings
    0 = >65% removal or beyond the area of the X
Adhesion Testing
(Rated according to ASTM D3359, Method B)

**DTM Coating A**

**DTM Coating B**

* Poor appearance

Wet Adhesion
Testing of DTM Coatings

- Water Resistance
  - Standard Humidity according to ASTM D2247, 35°C, 100% Relative Humidity chamber
  - Early Watersoak: coating is allowed to cure for 4 or 8 hours and is then immersed in DI water overnight

- Pendulum Hardness
  - Measures the damping time of an oscillating pendulum
  - König method, results reported in number of oscillations or time (1.4 seconds/oscillation)
  - Relative measure of the hardness of the coating
Testing of DTM Coatings

- **Blocking Resistance**

  - Coatings are drawn down on unpolished cold rolled steel panels with a 3 mil wet bar, allowed to cure for 1 or 7 days and cut into 1.5 inch strips
  - The strips are crossed face to face, perpendicular to one another and a 1 kg weight on a #8 rubber stopper is applied to the crossed panels for 30 minutes at room temperature or in a 50°C oven
  - Rated according to ASTM D4946 where 10 = no tack, 4 = very tacky, no seal and 0 = 75-100% seal
Testing of DTM Coatings

- Chemical Resistance
  - Chemicals are applied to a filter paper and covered with a watch glass
  - After 1 hour the filter paper is removed, the area is blotted to remove the chemical and the coating is scratched and evaluated for softening
  - The recovery of the coatings is evaluated 24 hours after chemical exposure
Testing of DTM Coatings

- Weathering
  - QUV (UVA and UVB), WOM and Florida Exposure

6 months exposure

24 months exposure
Testing of DTM Coatings

- Poor weather performance can result in corrosion as well as loss of gloss

6 months exposure

18 months exposure
Conclusions

- When formulating a waterborne DTM coatings, every component of the formula contributes to the corrosion performance.

- Binders have been developed that have very good corrosion resistance but must also be formulated for good film formation and with careful selection of additives and pigments.

- Replacing a resin in an existing formula may not result in optimal performance.

- Starting point formulations are guidelines for appropriate raw material selections.
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