Application Methods for Waterborne Coatings

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Agenda

• Waterborne coatings
  – types of coatings and how they are applied

• Application methods

• Formulation considerations
Where Are Waterborne Coatings Used?

- Architectural coatings
- Industrial coatings
  - Field-applied
  - Factory-applied
Architectural Coatings

- Residential and light duty commercial painting
- Interior / Exterior
- DIY and contractor applied

Types of coatings:
- Wall and ceiling primers and topcoats
- Gloss trim paints
- Specialty coatings such as:
  - Primers
  - Elastomeric wall coatings
  - Basement wall waterproofers

Application methods used:
- DIY mainly by brush and roller
- Contractor by brush, roller and spray
Industrial Coatings – Field Applied

- Light to medium duty industrial painting
- Interior / Exterior
- Contractor applied

Types of coatings:
- Industrial maintenance of steel and concrete
- Traffic and roadmarking paints
- Elastomeric roof coatings
- EIFS – Exterior Insulated Finishing System

Application methods used:
- Spray, roller and brush
Industrial Coatings – Factory Applied

- Shop and factory coatings
- Both manual and automatic application of coatings

Types of coatings:
- General industrial finishing of metal
- Wood and wood composite coatings
  - cabinetry
  - furniture
  - doors and windows
  - joinery, lumber, moldings
- Transportation
  - railcars
  - ACE
  - auto underbody, parts
  - truck chassis
Industrial Coatings – Factory Applied

- Types of coatings (continued):
  - Structural steel
  - Acoustic dampening
  - Coil coatings
  - Plastic coatings, e.g., business machines
  - Concrete and metal roof tiles
  - Fiber cement siding
  - Board coatings

- Application methods used:
  - Spray
  - Electrodeposition, autodeposition
  - Curtain, flow, vacuum coating
  - Roll coating
  - Dip
  - Electrostatic spray
How is the application method chosen?

The particular application method depends on:

• substrate being coated
• size and shape of surface
• speed requirements, i.e., how fast do you need to paint
• desired transfer efficiency
• type of coating
• desired coating thickness
Application Methods

Application methods used with waterborne coatings:

• Brush
• Roller
• Spray:
  Conventional
  HVLP
  Airless
  Air-assisted airless
• Dip
• Deposition:
  Electrodeposition
  Autodeposition

• Electrostatic spray:
  Ransberg disk
  Bell
  Hand gun
• Coaters:
  Roll
  Curtain
  Flow
  Vacuum
Brush

- Brush application is typically used for architectural and industrial maintenance painting

- Types of brushes:
  - Nylon
  - Polyester
  - Nylon/Polyester
  - Natural bristle
  - Foam

- Performance criteria important when applying by brush:
  - Flow - for minimization of brush marks
  - Brush drag - the “feel” of the paint
Shear rate of common coating processes
**Brush**

- Brush application is a high shear rate process
- ICI viscosity generally correlates well with brush drag
- When formulating WB coatings for brushing, use a rheology modifier that provides high shear viscosity
  - in particular, associative rheology modifiers
    - HASE
    - HEUR
Role of flow when brushing paints

- Flow - conventional wisdom says that flow should correlate with low shear viscosity (Brookfield viscosity). Although this may be true within a specific formula (binder, PVC, VS, etc), flow does not necessarily correlate with Brookfield viscosity when looking across a wide range of latex paints.
Techniques to understand brushing

- What are the size and time scales for flow of brushmarks?
- What causes brush marks?
- How is paint transferred from brush to substrate?
- Is there really a difference in brush drag between WB and SB paints?

Step 1: The Painter’s View
Time scale of brush flow

- Good flow
- Poor flow

Brush
Size of brush marks

Distance between peaks on order of $\frac{1}{2}$ to 1 mm
Individual brush bristles are much smaller – caused by bundles of bristles
How is paint transferred?

Step 2: The Substrate’s View
Brushing seen from underneath

White WB acrylic latex paint

Deep base
Brushing seen from underneath

- **Deep Base**
- **Bristle shafts loaded with paint, not touching substrate**
- **Bristles appear to touch substrate**
- **Leave valleys devoid of paint**
- **Bristle shafts that are bent over by contact with substrate have lost paint loading**
Brush Drag

- What we know (or think we know)?
  - Comes from high shear viscosity (ICI)
    - Controls film thickness, spreading, hiding
  - Painters complain / rave about it
  - Waterborne latex paint is typically 0.8 – 1.8 Poise
  - Alkyds have ICI viscosity = 4 – 5 Poise
- So, what would a latex paint with ICI = 4 – 5 Poise be like?
“Chart Pull” Measurement
Data for Latex Paint with ICI = 1.5

[Graph showing the force over time for Brushed Paint with ICI=1.5]

Dow Coating Materials
High vs Low ICI viscosity

Low vs. High ICI

ICI=1.5

ICI=0.7

Force (g)

Time

Dow Coating Materials
Brush drag vs ICI viscosity

$y = 15.879x + 47.899$
Roller

- Roller application is typically used for architectural and industrial maintenance painting.

- Types of roller covers:
  - Synthetic
    - Nylon
    - Foam
  - Natural
    - Lamb’s wool

- Performance criteria important when applying by roller:
  - Spatter resistance
  - Stipple pattern
Roller Spatter

Controlled by formulating with associative thickeners

- No Spatter
- Spatter

Associative thickener

HEC thickener

Dow Coating Materials
Close-up of HEC containing paint
HEC containing paint with foam roller

Strings come from bumps

Strings break up

No Strings where there’s ribbing

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Spray

- Spray systems are designed to atomize paint and deliver coating to the substrate as a fine spray.

- Several spray application methods are available:
  - Conventional spray (LVHP)
  - HVLP
  - Airless
  - Air-assisted airless
  - Electrostatic

- Both manual and automated systems are available.
Formulating for Spray Application

Main issues when formulating WB acrylics for spray application are:

**Viscosity**: Need the right viscosity for delivery to spray tip, as well as for sag control when applied to vertical surfaces

**Foam / Microfoam**: Microfoam generation is especially an issue with airless spray. Choice of defoamer/deaerator can be critical, as well as factors that help keep the film open longer (e.g., VS, water miscible co-solvents).
**Microfoam**

Two mechanisms are suggested to explain the dissipation of microfoam:

- Microfoam bubbles coalesce into a larger bubble, which rises to surface and bursts

\[ V \sim \frac{r^2}{\eta} \]

- Microfoam bubbles collapse upon themselves as gas (air) in the bubbles dissolves into the continuous phase (water)

Conventional Air Spray

- Also called LVHP (Low Volume / High Pressure)
- Using a specifically designed gun, high pressure air (40-90 psi) atomizes a liquid stream of paint into a fine spray
- Produces the finest spray, hence best looking finishes
- Typically spray at 6” to 12” from surface
- Low transfer efficiency (30 – 60%) due to overspray and bounce-back
- Typical viscosity for waterborne acrylic coating:
  20 to 30 seconds #2 Zahn cup
Conventional Air Spray Guns

Air is supplied by a compressor. Coating is supplied to gun by one of the following methods:
Conventional Air Spray

**Advantages**
- High level of control
- High versatility
- Low capital investment
- Produces smooth, high quality finish
- Can be used with a wide range of coating materials

**Disadvantages**
- Low transfer efficiency
- High compressed air use
- Overspray and bounce-back due to high volume of air
- Poor coverage of recessed spaces / corners
HVLP Spray

• HVLP = High Volume / Low Pressure Air Spray

• Uses larger diameter nozzle opening along with a high volume of air (10-30 cfm) at low pressures (0.1-10 psi) to atomize paint

• Air supplied by compressor or air turbine

• Paint supplied by siphon, gravity and pressure feeds

• Higher transfer efficiency than conventional air spray, typically 65 – 75%

• Excellent for close work; typically spray 6” to 8” from surface

• Typical viscosity for waterborne acrylic coating:

  20 to 25 seconds #2 Zahn cup
HVLP Spray

**Advantages**
- Reduces overspray and bounce-back
- Good transfer efficiency
- Sprays well into recesses and cavities
- Lowers cleanup costs, reduces filter replacement costs
- Can convert to HVLP from conventional spray systems

**Disadvantages**
- Atomization may not be good enough for fine finishes
- May not be able to operate with high production rates
**Airless Spray**

- Does not use compressed air to atomize paint
- Paint is pumped at high fluid pressures (500-6,500 psi), by an air-driven reciprocating fluid pump, through a small orifice at spray gun tip
- Sudden pressure drop at front of gun creates atomization
- Heavily used by contractors in architectural and industrial maintenance painting
- Low to high viscosity paints can be used. Typical WB acrylic maintenance paints are 90 – 100 KU. No thinning is necessary.
Airless Spray Equipment

- Pump is driven by compressed air, but no air mixes with paint.
- Spray tips use a safety guard, because high pressures pose an injection hazard.
- Tips are reversible to aid with clogs.
Airless Spray

- Produces a “softer” and less turbulent spray because there are not large volumes of air accompanying the atomized coating.
- Transfer efficiencies typically 65 – 70%.
- Less bounce-back and can paint into recessed areas better.
- Typically spray at 12” to 18” from surface.
- Gives a heavier coat of paint in a single pass.
- Droplets of atomized paint are generally larger than with conventional spray – more difficult to produce high quality finish.
- Control fan size and degree of atomization by changing tip size (vs by changing air pressure with conventional spray).
Airless Spray

Advantages

• High rates of paint flow – good for painting large areas
• Good transfer efficiency, due to less turbulent spray
• Easy gun handling (no air hose)
• Ability to apply high viscosity paints
Airless Spray

Disadvantages

• Relatively poor atomization vs air spray
• Reduced control of fan pattern – need to change tips
• Fan pattern and flow rate changes as tip wears due to abrasion
• Tendency for tip clogging due to small orifice
• Dangerous to use and clean due to high fluid pressures and hazard of skin injection
• Greater maintenance required vs conventional
Air-assisted Airless Spray

- Variation of airless spray
- Supplemental air jets guide paint spray and break up large droplets, increasing level of atomization
- Quality of finish is improved relative to airless
- Typically uses:
  - 150 - 800 psi fluid pressure
  - 5 - 30 psi air pressure
- Can provide lower fluid delivery rates than airless, and can result in better transfer efficiencies
- Same hazards as airless spray
- Low bounce-back

Dow Coating Materials
Electrostatic Spray

- Paint can be atomized using conventional air, airless, or rotary (Ransberg disk and bell) systems.
- Atomized paint droplets are charged by an electrode.
- Charged paint droplets are attracted to grounded substrate.
- Charge difference between paint and substrate creates a “wraparound effect”, where particles fly past substrate and reverse direction, coating the back and sides of the part.
- In rotary systems, centrifugal force generated by disc or bell atomizes paint, which drives it from the nozzle past electrode.
- In hand gun systems, an electrode located at tip of hand gun charges atomized particles.
Electrostatic Spray

**Advantages**

- High transfer efficiencies (65 - 95%)
- Produces very little overspray
- Produces a uniform coat

**Disadvantages**

- Limited coverage of complex shapes due to Faraday cage effects
- Only useful on conductive parts
- Possible shock and fire hazard
Dip Coating

- Parts are dipped manually or by conveyor into a tank of paint
- Process is used primarily for primers and coating whose appearance is not important and where color is always the same
- Dip coating is not suitable for parts with cavities or hollows that can trap paint
- Rotation during dripping is recommended to improve finish quality
- High transfer efficiency
Formulating for Dip Coating

Main issues when formulating WB acrylic coatings for dip coating application are:

**Viscosity**: Typical viscosity is approximately 20 – 25 seconds on #2 Zahn cup. Film thickness is controlled by viscosity, as is beading of paint as it drips and dries.

**Skinning**: Prevention of skinning on surface of dip tank. Often a water-miscible co-solvent, such as dipropylene glycol, will help prevent skinning. Agitation / mixing of the paint in tank is also effective.
Dip Coating

**Advantages**

- High production rates
- High transfer efficiency
- Can closely rack parts, unlike for spray applications
- Coating thickness does not depend on operator skill

**Disadvantages**

- Extremely dependent on viscosity of the paint
- Not suitable for items with hollows or cavities
- Slow to change colors
- Can be a fire hazard with open tanks of solventborne coatings
- Poor to fair appearance – need to rotate parts for best appearance
Electrodeposition

- Also called E-coat, electrophoretic coating, electrocoating

- Paint film is deposited onto a grounded substrate (usually steel) when placed in a dilute (10 - 20% solids) waterborne coating that is electrically charged.

- Commonly used with epoxies and acrylics

- Produces a uniform, corrosion resistant film

- High transfer efficiency – greater than 90%

- Typical viscosity of WB acrylics is low, approximately 16 to 20 seconds on #2 Zahn cup
Electrodeposition process

Electrodeposition coatings are classified as either:

- **anodic** - paint particles are negatively charged
- **cathodic** - paint particles are positively charged
Electrodeposition coating is a multi-step process involving cleaning of the metal surface, pretreatment, water rinsing, deposition of the coating film, a rinse to remove “paint drag-out”, and finally curing in an oven.
Electrodeposition

Advantages

• Over 90% transfer efficiency
• Uniform coating on all surfaces reached by electricity
• High production rates and can be fully automated
• Has low VOC and HAPs emissions

Disadvantages

• High energy demands, high initial capital outlay
• Substrate limitation – must be electrically conductive
• Has coating thickness limitation – “self insulating”
• Masking can be costly if sections need to be uncoated
• Requires separate lines for each color
• Requires high level of employee training
Autodeposition

- A multi-step immersion process used to deposit organic coatings on iron, steel, zinc and zinc alloy substrates without the use of electricity.
- Deposition of coating is based on a chemical reaction of a mildly acidic coating bath with the metal surface.
- Typical solids content of bath is 3 to 7%.
- Process is self-limiting with regards to film thickness - as the film is deposited, it slows and eventually stops the reaction. Typical DFT is approx. 0.6 to 1.2 mils.
- Results in a very reproducible, uniform film thickness, even on parts with complex geometries.
- Limited in colors offered.
**Autodeposition mechanism**

\[ 2 \text{FeF}_3 + \text{Fe}^0 \rightarrow 3 \text{Fe}^{+2} + 6 \text{F}^- \]

- ○ = stable latex
- ○○ = latex destabilized by Fe\(^{+2}\) ions
- Steel substrate
Autodeposition coating is a multi-step process involving cleaning of the metal surface, water rinses, deposition of the coating film, a reaction rinse, and finally curing in an oven.

Autodeposition

**Advantages**
- High transfer efficiency (average approx. 95%)
- Drag-out effects are minimal due to low bath solids
- Uniform coating on all surfaces
- Coatings deposits only on metal surfaces of part
- Can coat complex parts and assemblies
- Low VOC emissions

**Disadvantages**
- Substrate limitation – only metal (Fe, Zn, Zn alloys)
- Has coating thickness limitation as coating slows reaction
- Limited colors available
- Requires high level of employee training

Dow Coating Materials
Roll Coating

- Process involves applying a coating to a flat substrate by passing it between rollers.
- Paint is transferred by one or more pickup rolls onto an application roll, which applies the paint onto the substrate.
- After curing, the substrate can be shaped or formed without damage to the coating.
- Limited to flat stock, such as boards and coiled metal.
- High transfer efficiency and production rates.
- Two types of roll coating processes:
  - Direct
  - Reverse
Direct Roll Coating

Direct Roll - applicator roll rotates in the same direction as the substrate
Reverse Roll Coating

Reverse Roll - metal feed stock is fed between the rolls as a continuous coil. Applicator roll rotates in opposite direction of the substrate, and paint is wiped onto substrate.
Coil coating is a continuous process where metal sheets up to 72” wide are coated while moving at velocities up to 700 feet per minute.
### Roll Coating

**Advantages**
- High transfer efficiency
- Uniform coating thickness
- High production rates

**Disadvantages**
- Suitable only for flat stock
- "Ribbing" can be caused by poor flow
Curtain Coating

• Curtain coating uses a waterfall flow of paint to coat parts on a conveyor belt.
• The paint flows at a controlled rate from a reservoir through a wide variable slot.
• High transfer efficiency and uniform coverage.
• High line speeds (100 – 500 ft/min)
• Broad thickness range (0.5 – 25 mils/pass).
• Process is suitable only for relatively flat stock.
• The quality of the finish depends on the viscosity of the paint.
Curtain Coating Process

Coating Head (pressure)

Conveyor

Paint Curtain

Board

Reservoir

Pump
Formulating for Curtain Coating

Main goal when formulating WB acrylics for curtain coating is to obtain a stable curtain with low foam generation:

**Surface tension:** Low surface tension aids stability of curtain. Chose surfactants to achieve a surface tension of approximately 40 – 45 dynes/cm.

**Foam control:** Must balance surfactants with defoamers. Also avoid freefall of paint into collection tray and use low shear pumps.

**Viscosity:** Avoid high viscosity for better foam release. Typical viscosity is approximately 20 – 25 seconds on a #4 Ford cup.
Curtain Coating

_Advantages_

- High transfer efficiency
- Uniform coating thickness
- High production rates

_Disadvantages_

- Suitable only for flat stock
- Requires low surface tension, low foam
- Highly dependent on viscosity

  low viscosity = curtain breaks
  high viscosity = air entrapment
Vacuum Coating

• Vacuum coating is used to coat substrates with a uniform cross section
• The piece enters the coating chamber through a low tolerance opening (~0.125") of the same profile
• Coating is applied to all or selected surfaces in the chamber, and excess is removed via vacuum
• Very high transfer efficiency (100%)
• High line speeds (~100 ft/min)
• Film thickness controlled by vacuum pressure, line speed and tolerance of slot opening
• Used for coating molding, joinery, pipe, etc
Vacuum Coating Process

Paint supply

Paint Chamber

Conveyor

Pipe

Pump
Vacuum Coating

**Advantages**
- High transfer efficiency (approx. 100%)
- Uniform coating thickness
- High production rates

**Disadvantages**
- Suitable only for substrates with constant profile
- Viscosity may need to be adjusted if water / thinner is removed by vacuum
- Coating can build up on inside of chamber
- Foam can be an issue
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