Curtain Coating
EDGE CONTROL

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Curtain Coater Formats

Slot curtain coater

Slide curtain coater
Curtain Coating Characteristics – Resultant Benefits

CHARACTERISTICS:

• Pre-metered → accurate coating thickness

• Optimized, precision manifold → uniform CD coating thickness

• Relatively high liquid impingement momentum “hydrodynamic assist” → air entrainment onset shifted to high speeds
Process Characteristics – Resultant Benefits (continued)

• Robust impingement flow allowing coating
  – of uneven webs
  – over some splices
  – overboard of web edges
  – of unsupported web in spans

• Curtain height: large applicator-to-substrate clearance resulting in
  – relaxed clearance precision
  – no trapped particles
  – low substrate stress
  – projection coating giving contour coverage
Process Characteristics – Resultant Benefits
(continued)

• Laminar flow throughout & gravitational leveling on slide die surface
  PRECISION, SIMULTANEOUS MULTILAYER CAPABILITY
Limits of Operation - “Coating Window”

Puddling at impingement

Curtain disintegration

Air entrainment

Curtain stability

Volumetric Flow Rate/Width

Web Speed

Operating Window
Curtain coating process parameters

- Flow rate / width
- Surface tension (dynamic)
- Rheology
- Substrate characteristics (roughness, porosity)
- Curtain height
- Impingement angle
“Reduction to Practice”

- Air boundary layer suppression
- Shielding from spurious air currents
- Starting and interrupting curtain flows
- Curtain edge control
“Free” Curtain Edges

Curtain edge flow without active control: “Free” Edges
Lateral contraction
• Surface tension driven
  (balance of surface tension and falling liquid momentum)
• Effect worse with taller curtains
• Heavy flow along edges
Free Curtain Edges – no edge control

Applications not requiring curtain edge control:

Overboard Coatings
- Excess coating width
- Flow well above minimum for curtain stability
- Recirculate excess flow
  - Stable solution / suspension
  - Must be easy to recirculate—back to delivery or to prep
- Dispose of excess liquid
  - Inexpensive liquid
  - Inexpensive disposal treatment

Pilot Plant coater under operation 1200 m/min - graphic paper

Courtesy of Voith Papers
Edge Guide Systems

Applications requiring Curtain Edge Control

- **Inboard Coating** (inboard of web edges)
  - At least modest coating uniformity required
  - Expensive liquid (or too expensive to discard) and/or cannot recirculate (multilayer, PSA)
  - Dry edges required

- **Overboard Coating**
  - Reduce excess flow width: reduce waste (expensive liquid and expensive substrate) or amount to recirculate
  - Guided smooth flow to minimize foaming prior to recirculation

- **Low flow rate** (near minimum for curtain stability)
Curtain Edge Guides

- Edge guide basic task:
  **Prevent curtain edge contraction**

- **Ideal** Curtain Edge Guides:
  - Allow a flow field and its surface envelope identical to that present in the curtain interior
  - Result: no lateral gradients in important flow and geometrical parameters such as liquid velocity, curtain thickness, surface tension, etc.
  - Benefits: no curtain edge contraction, uniformity, resists air entrainment

- Reality:
  Solid boundary element
  A CHALLENGE!
Simple guide design – Rods/Wires

• Benefits:
  – Easy set-up
  – Adjustable
• Diameter effect
• Disadvantages:
  – Curtain detachment risk
  – Curtain guided start difficulty
  – Recovery from curtain movement difficulty
Simple guide design – Flat Plates

- Benefits/Advantages:
  - Curtain attachment more stable
  - Promotes automatic-start
  - Conducive to curtain transient motion
  - Allows curtain deflection with slide die

- Disadvantage:
  - Uniformity near edge (sensitive to static contact angle)
Simple guide design – Weaknesses

• Viscous drag along guide:
  – Blassius boundary layer
  – Deficit in edge region impingement momentum on web

Associated problems:
  – Premature air entrainment near edges
  – Curtain vulnerable to rupture near edges at lowest flow rates

• Non-uniform edge region coating
• Contamination/buildup on guide surface
Suitable applications for simple edge guides:

- Moderate coating speed
- Non-critical uniformity in edge region:
  - Excess drying/curing capacity
  - Product uniformity not critical
  - “Acceptable selvage” of off-quality edge lanes
- Non-contaminating liquids (or slowly contaminating liquids with short productions)
- Adjustable curtain height requirements
Challenging Edge Control Situations

- High Coating Speed (air entrainment near edges)
- Low flow rate (curtain stability)
- Critical uniformity required
- Complex and/or difficult rheologies (contaminating, sticky, etc)
- Multilayer application
- Slide-curtain coating (deflection to underside)
Guides with “Lubricating” Edge Layer

- Low viscosity solvent / water layer between solid guide surface and curtain liquid edge
- Contains velocity gradient in a relatively thin, low viscosity layer
- Allows greater acceleration of curtain-edge liquid
Edge flow – Additional benefits, but also challenges

Additional benefits:
– Promotes wetting attachment between coating liquid and edge guide surface
– Promotes auto-start of guided curtain edges
– Flushes and protects the guide surface from contaminating coating liquid

Challenges:
– Edge flow introduction without disturbing the curtain flow
  • Stationary wave in curtain
  • Inlet ports on curtain guides
  • Ports on slide flow edging plates
– Edge layer stability
  • Layer thickness
– Edge flow extraction
  • Suction ports
Guides With Edge Flow
example: Kodak’s Dual Wire Guides
Guides With Edge Flow
example: TSE’s Porous Plate Guides
“Problem Edges”

For those “Bad Edge Days”:

Heavy-edge Removal Devices
CONCLUDING OBSERVATIONS

- Curtain coating is an extremely capable thin liquid film coating method - arguably the best - if an application fits within its coating window.

- Actual curtain coating practice requires certain practical accompanying technologies such as capable manifold design, air handling and edge guides.

- Controlling curtain edges against surface-tension driven contraction is essential in most applications.

- Actual guides are not ideal, but satisfactory systems are available for most applications.
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