1. Prologue
2. Requirements
3. Basics of slot coating
4. Curtain Coating
5. Bead Coating
6. Conclusion

From Curtain Coating To Bead Mode Slot Die Coating – Contact Free Coating Procedures For Thin Functional Coating Layers

Presented by
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“High Performance Coating” is only possible, if the process is completely understood in terms of physical aspects.
Areas of application

- Epoxy resin coating and impregnation for light construction materials
- Anodes, cathodes and separator film coatings for lithium ionic batteries
- Organic and printed electronics
- Nano layers ≥ 50 nm on flexible materials (nanotechnology)
- Membranes for water treatment and salt water desalination

High performance of the coating necessary:
- Coating **absent of defects**
- **Cross-Web Distribution** less than +/-1%
- **Coating thickness** must remain **constant** over **24h** of production

⇒ **Contactless and premetered coating**
Coating Methods

Self-Metered Coating Techniques

⇒ **Self-Metered-Coating** means that the applied *coating weight depends* on the process => e.g. Dip-Coating, Roller-Coating, Knife-Edge-Coating

Pre-Metered Coating Techniques

⇒ **Pre-Metered-Coating** means that the applied coating weight does **NOT** depend on the process => e.g. Slot-Die-Coating, Spray-Coating
### Principle of pre-metered coating

#### Pre-metered means, that the wetfilm thickness does not depend on the process, e.g.:
- Surface tension, viscosity
- Distance between slot die and substrate

#### The coating weight can be controlled, if the following parameters are known:
- Massflow
- Substrate velocity
- Density of the coating fluid
- Coating Width

\[ \dot{m} = \rho \cdot U_w \cdot h \cdot B \]

- \( \dot{m} \): Massflow
- \( U_w \): Substrate Velocity
- \( B \): Coating Width
- \( h \): Wetfilm thickness
- \( \rho \): Density
⇒ The cross-web distribution depends on the **design** and the **precision of the slot die**, but not so much on the process

⇒ Nevertheless the **process must be understood** in order to guarantee excellent coating qualities

\[
\dot{V} = \frac{\Delta p b^3}{12 \mu L}
\]

\[
\frac{\Delta \dot{V}}{\dot{V}} = 3 \frac{\Delta b}{b} + \frac{\Delta (\Delta p)}{\Delta p} - \frac{\Delta L}{L} - \frac{\Delta \mu}{\mu}
\]
Peripheral components

Most important components:
- Feed bin / vessel
- Pressure vessel or pump
- Filter Unit
- Massflow-Meter
- Slot Die

Big Advantages:
Closed System => NO contact with the atmosphere
NO recirculation of the fluid
NO evaporation of the fluid

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Different Setups

- Web Tension Mode
- Extrusion Coating Mode
- Bead Coating Mode
- Short Curtain Coating Mode
- Long Curtain Coating Mode

⇒ !!! Process not understood => Trouble with the coating 😞
⇒ !!! Lets understand the process 😊
Stability regions of curtain coating

Curtain

Impingement-Zone

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Curtain stability, I

Condition for a stable curtain: **Curtain Velocity** must be **higher** than the **velocity of the disturbance** (air, particle etc.)

\[ V_T = \frac{2\sigma}{\rho b} \]

\[ u > V_T \]

\[ \dot{m}_c > \sqrt{2\sigma \rho b} \]

\( \sigma = \text{Surface Tension} \)
\( \rho = \text{Density} \)
\( b = \text{curtain thickness} \)
\( \dot{m}_c = \text{Minimum massflow} \)

⇒ Curtain stability depends on fluid properties and on the slot width
The minimum massflow, which is necessary to create a stable curtain, depends also on the viscosity.
Coatability depends strongly, among other parameters, on the impingement velocity, the substrate velocity and the viscosity.
Limitations of curtain coating

⇒ In order to coat 10 g/m² in curtain-mode the substrate velocity must be at least 650 m/min for low viscous media

⇒ How is it possible to coat less than 10 g/m² at substrate velocities of less than 100 m/min?
Principle of bead-coating

⇒ Operating the same slot die in bead-mode

- Characterized by:
  - Capillary forces acting between slot-die and the substrate
  - Distances between slot die and substrate of less than 1mm
  - Very low wet film thicknesses (~ 1µm) are possible at substrate speeds of less than 100 m/min
  - Wet film thicknesses can be obtained at substrate distances which are 300 times larger than the wetfilm thickness
Flow phenomena of bead-coating

- Flow between slot die and substrate is an overlapping flow of a shear-driven (a) and a pressure-driven flow (b)
- For \( d > 2h \) \( \Rightarrow \) A subpressure exists between slot die and substrate
- The back meniscus stabilizes the process

\( \Rightarrow \) Very low wet film thicknesses at moderate substrate distances
Coating Window (Operation)

- The calculation of coating windows helps to control the process
- The following parameters are important
  - Fluid parameters (viscosity, surface tension)
  - Process parameters (distance between slot die and substrate, wetfilm thickness, substrate velocity)
  - Lip length of the slot-die
In this example a maximum velocity of 20 m/min would be possible, without applying a subpressure at the back meniscus.

A wetfilm thickness of 12 µm (h) can be applied at a distance between the slot die and the substrate of 320µm (d) => d/h=26
Conclusion

⇒ **Slot Coating** is a *premetered* coating technique => wet film thickness does not depend on the process

⇒ A slot die can be *operated* in *different setups*, such as curtain-coating-mode or bead-coating-mode

⇒ Important is to *understand* the process

⇒ **Curtain Coating** => Curtain stability and coatability in the impingment zone are important

⇒ **Bead Coating** => Back meniscus must be able to stabilize the process

If you want to know whether **YOUR fluid** can be coated with a *slot die*? ...
Thank you for your attention!

For further information don’t hesitate to contact us any time:

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