Motivation for the development by BMB / summary

Curtain-coating is a well known and state of the art coating method especially in the photo and film industry and for other special applications like carbonless papers, thermosensitive or ink jet material.

BMB studied the fundamentals of this technology, advanced the method and brought it deliberately to market maturity, especially for coatings of water based pressure sensitive adhesives.
The main motivation to develop a new method for the coating of pressure sensitive adhesives was due to the market demand for higher production speeds on coating lines. Apart from this demand, BMB's other important goal is achieving an improved coating surface with our coating heads. This should finally lead to a possible reduction of the coating weight for given functional requirements of a coating.

The basis for our development: slot die coating

This is a classic arrangement of a precision slot die coater working with a steel or rubber covered backing roll.

Slot die coating is well known in the self adhesive industry. The method has a number of distinctive advantages over conventional methods, which are:
Best attainable cross profile performance

Excellent coating appearance

Flexible, clean application

Slot die coating as we know has also a number of disadvantages:

- very little distance between die lip and substrate (particularly at low wet coating weight)
- danger to damage die lip by the substrate
- sensitive to smallest dirt sediments and air bubbles
- danger to damage die lip by operating staff
- air ingress in case of setting parameters not being carefully observed
- speed limitation due to air ingress
- interruption of the coating procedure for splicing
- change of working width in a wide range extremely difficult
- in case of contamination extreme effort for cleaning

Why curtain-coating?

The motivation for this development is to keep all the advantages of slot die coating and achieve considerable improvements in the following areas:

- substantial increase of coating speed
- reduced precision standards of construction on die and especially coater framework
- less chances to damage the lips
- simple change of width possible
- large distance between die and web
- change of thickness of the substrate without major consequences
- reduced pressure impact to the substrate: less web-breaks
- no interruption of coating when splices go through the coating head
- high solids content possible: efficient drying, energy savings
Requirements for BMB curtain coating / general overview

Criteria for curtain-formation:

- viscosity / dynamic viscosity of the coating mix
- low surface tension / dynamic surface tension of the coating mix

Criteria for good coating:

- sufficiently low viscosity
- visco-elastic behaviour
- high surface tension of substrate
- impact: curtain height, density of coating mix
- coating quantity
- substrate surface: smoothness, porosity

Adhesive supply / preparation:

- efficient filter system
- consistent temperature of coating colour and die
- minimum air content in colour
Specific factors of curtain-coating, conditions and limits

Like for every coating method, the medium properties are of great importance. For curtain coating, this mainly concerns the rheology and the surface tension. In order to ensure the satisfactory creation of a curtain, a minimum flow related to the coating's viscosity and surface tension, must be established.

Equipment for Static Tests
Curtain-Coater on BMB-Pilot-Coater
Falling height / falling speed / curtain thickness / film thickness

\[ \dot{Q} = \frac{\kappa \alpha}{v} \]

\[ v = \frac{\dot{Q}}{A} \]

\[ v, \text{ at } 6000 \text{ml/min and } D_1 = 0.3 \text{mm: } 0.33 \text{m/s} \]

\[ v = v_1 + \sqrt{\frac{v_1^2 + 2gH}{g}} \]

\[ D_2 = D_1 \cdot \frac{v_1}{v} \]

\[ D_3 = D_2 \cdot \frac{v_2}{v_1} \]

for \( v_1 = 300 \text{m/min and } H = 150 \text{mm:} \)

\[ v_2 = 2.04 \text{m/s} \]

\[ D_2 = 0.049 \text{mm} \]

\[ D_3 = 0.020 \text{mm} \]

Falling speed depending upon exit speed and curtain height

![Graph showing falling speed vs curtain height](image)
Minimum wet coat weight

Minimum flow rate for correct curtain formation:

0.5-1 ml/s, cm = 3000-6000 ml/min, m

at Rho = 1 g/cm³: 3000-6000 g/min, m

at 100 m/min: 30-60 g/m²
Coating window

There are several borderline cases.

Formation of heel:

When the curtain is no longer completely removed in the direction of the web, but flows slightly in a reverse direction, this is known as heel formation. These so called "heels" are unstable zones and contain whirls, causing coating flaws. Heels with air intake may form if the viscosity is too low and the web speed is too high. The air boundary layer is no longer entirely replaced.

It is ideal when the curtain hits the fall line and forms no heel or only a very small heel.

Formation of strands:

If the curtain tears open, due to insufficient mass flow, it contracts into strands. A minimal flow, depending on viscosity and surface tension is therefore necessary.
Influence of the dynamic surface tension of the coating medium:

This very important value should be as low as possible. If the surface tension is too high, no curtain forms or the medium contracts if minor disturbances occur. Furthermore, the wetting procedure at the impact line is disturbed. Also the curtain must glide on the special lateral edge guiding bars, that is only possible with a suitable surface tension.

Influence of air bubbles:

Air bubbles cause more problems after the application point than inside the curtain. Either the bubbles crack in the wet film before drying, causing holes in the coating, or they crack in the dryer. In order to prevent this, the coating mass must be free from air.

Influence of the substrate:

The substrate's influence is very strong, not only because of its topography but also because of its wetting characteristics (hydrophilic and hydrophobic characteristics, penetration behaviour, etc.). Our tests also show that web material with smooth surfaces like films are easy to coat. Since the layer, due to the small impact forces, rests upon the surface, there has to be given special attention to the anchoring.

Influence of the viscosity:

The viscosity has an influence on the curtain formation and the coating process. The viscosity should not be too high, in order to allow the curtain to fall and accelerate under its own weight.

Air intake:

If the web speeds are high and depending on the nature of the surface of the substrate, air can penetrate between curtain and web, which causes problems for the entire coating (= wetting) procedure. In order to avoid this, the air boundary layer is to be removed with suitable measures.
Pulled film:

This occurs when the curtain does not hit the substrate on the impact line but is pulled forward together with the web. This occurs particularly if the viscosity is too high. If the viscous forces overtake the impulse forces, the curtain is torn from the vertical position. This also leads to coating flaws.

Due to the surface tension the curtain contracts or there is a neck-in, a term which is also used in the film manufacturing industry. This contraction must be eliminated by guiding the curtain laterally.

The curtain needs to have a minimum force, so that the coating / wetting procedure will occur; this force is called impulse and is related to the flow rate and the curtain speed.

As normally the coating quantity is fixed, the impulse can only be changed by the speed. Due to gravity, the falling curtain accelerates and proportionally pro rata thinner. This impulse force, dependent on the mass flow rate and speed, has now to penetrate completely the air boundary layer on the substrate. The faster the web speed, the greater the air boundary layer which is drawn along and therefore needs to be removed.
Configurations of the Coating Head

Dispositions coating Head, Variations
Major advantages of the BMB curtain coater

Cost reduction:

- potential of coat weight reduction while the same functional properties of the coating are retained, therefore reduced drying requirement become an additional bonus
- minimum cross section coat weight tolerance
- highest coating speeds possible
- lowest drive rating requirement of the coater, maximum one (1) driven roll
- no wear & tear of rubber covered rolls, engraving on rolls, metering bars, etc.

Excellent coated surface:

- no film splitting effects (compared to roll coating)
- very smooth, structure-free surface
- high-quality end products
- changes of thickness of the substrate without negative implications

Flexible, clean application:

- simple and easy change of coat weight (variation of pump rotational speed)
- wide range of coat weights
- wide range of viscosity
- no (or low quantity) of coating medium in circulation
- cleaner operating environment
- easy method for width changes
- clean, uncoated edges

As a conclusion, BMB is convinced that curtain coating has the potential to lead us into the next century as the coating method.