Precise Coating With Premetered Die Technology

Abstract

The speech shows the advantages of the premetered coating processes based on the technological principles.

The TSE- die design consists of a dual chamber fluid distribution system. The main goals of the die optimization are: the uniform cross-web film thickness, covering a big range of liquids and application points and that the die has a self cleaning effect.
During this iterative process a design will be selected which allows producing all products in top quality.
Thanks to the excellent precision of the TSE Troller die, costs and resources can be reduced.
Coating functional layers in high precision and avoiding maintenance costs help achieve competitiveness and maintaining production success.

1. Pioneering Premetered Coating Solutions

Fifty years of know-how in the development and production of premetered coating dies have made TSE Troller a world leading specialist in the applied coating technology sector. The company based in Murgenthal, Switzerland, has developed advanced coating solutions which have paved the way for the future.
TSE Troller brings you the benefit of unrivalled precision tailored to your specific needs. Our coating dies, designed exclusively for premetered applications, satisfy almost all coating needs. We specialize in high precision multilayer coating and complex coating dies. At TSE Troller we maintain secrecy about our own achievements and those of our customers. Our best reference is silence. Therefore don’t ask about it. But ask.

2. Process Description Of Premetered Coating

Premetered coating methods are a group of technologies which are used for the continuous application of functional fluids on substrate in web format. Unlike the “self-metering” methods, a uniformly operating pump delivers the necessary volume of fluid to maintain the desired wet film thickness on the substrate to be coated for a given working width and at the planned working speed. This fluid quantity is held constant, e.g. by flow control. The coating liquid is then distributed over the desired working width by means of a coating die. For this purpose, a distribution system consisting of a distribution chamber and a subsequent metering slot is incorporated in the die. The design of this distribution system, in terms of flow technology and the uniformity of the metering slot height, are the key contributory factors to uniform distribution of the fluid across the working width. The coating fluids may contain water or organic or inorganic solvents and for some applications may be used without a solvent (100% solids). As in the case of all other coating techniques, the properties of the fluids must be adjusted to the needs of the premetered techniques.

3. Self-Metered vs. Premetered Coating Systems

Self-metered coating systems (see figure 1) have been standard in the industry since the industrialization of coating while premetered methods were introduced during the middle of the last century by the photographic industry. Since then it has also become state-of-the-art technology in the special paper or adhesive industry.
The advantages of premetered coating systems (see figure 2) such as very uniform cross profile, optimized and low liquid consumption, higher coating speed and the possibility to coat several layers simultaneously has further spread these methods into many new fields of the industry. While the liquid formulation and viscosities in self-metered systems do change from the beginning to the end of the batch, the formulations in the premetered systems remain the same over the entire batch. This results into uniform coating thickness in longitudinal direction. The achievable cross profile tolerances are much narrower in case of the premetered systems as compared to self-metered systems. Therefore, with premetered coating the liquid savings are significant. Due to short residence time in optimized dies it is possible to coat reactive fluid systems, which gives more freedom in designing functional layers.

Self-Metered Coating System

Example: Pan (Dip) Coating

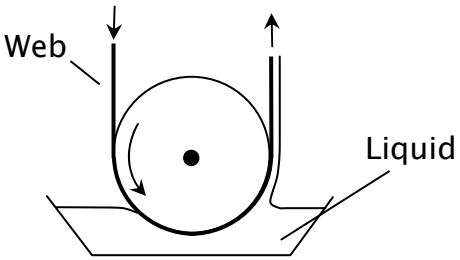

Figure 1

- Simple methods
- Lay down depends on properties and web speed
- Formulation changes affect lay- down
- One layer applied at the time

Pre-Metered Coating System

Example: Dual Layer Slide Curtain Coating

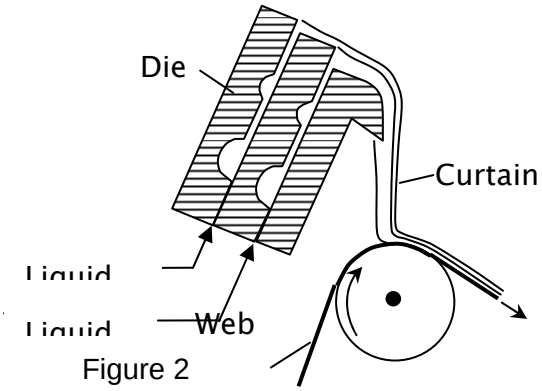

Figure 2

- More complex, requires a die distributor
- Lay down is specific within operating range of process
- Formulation changes do not affect lay down
- Multiple layers coated simultaneously
- Multi component liquids usable

4. Curtain Coating

The curtain coating technique enables layers ranging from thin to thick to be applied. The application area ranges from moderate to very high coating speeds, well above 2’000m/min. Curtain coating methods enable one or more fluid layers to be applied in a single operation. The number may exceed ten to suit the particular application and depends on the shape of the coating die, slot die (see figure 3) or slide type die (see figure 4). When the curtain coating method is used, the die lip is positioned at a great distance above the web to be coated, the fluid drops downwards in free fall as a closed liquid curtain and is deposed on the substrate.
In the case of the curtain coating method with a slot die, the exit slot is orientated downwards while in applications with a curtain slide die the fluid film leaves the exit slot(s) upwards and then flows down the inclined surface ("Slide") before leaving the die body at the lip and passing into the curtain. Because of the great distance between the lip and web, the curtain coating method is largely unaffected by linear coating defects and produces a very uniform layer on uneven surfaces (contour coating). For this application method too, TSE develops and produces coating dies and also various accessory components which are used to optimize the application window.

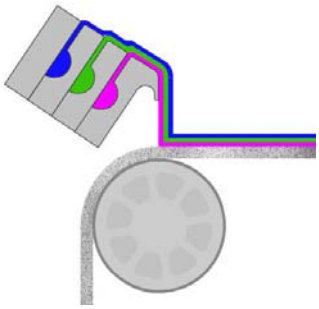

Figure 3

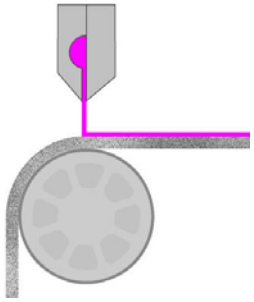

Figure 4

5. Slide-Bead Coating

The slide-bead coating technique enables layers of medium to large thickness to be applied. The application range extends from rather slow coating speeds up to average speeds of 300-400m/min. Slide-bead coating enables one or more fluid layers to be applied in a single pass to the substrate which is to be coated; the number of layers may exceed ten, depending on the particular application.
When the slide- bead coating method is used, the fluid film emerges from the exit slot of the die (see figure 5) in an upward direction and then flows down the inclined surface ("Slide") before bridging the narrow bead gap between the die lip and the running web– in much the same way as when the slot-bead coating method is used.
To achieve the most uniform possible film thickness on the substrate to be coated in cross-machine direction, the parallelism of the bead gap must be set with great precision as must the slot height. An inherently stable and highly accurate positioning system is required. For this purpose, TSE develops and produces coating dies and also various accessory components which are used to optimize the application window.

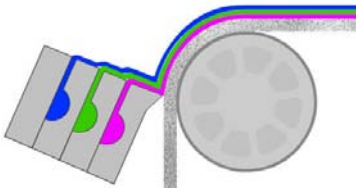

Figure 5

6. Slot-Bead Coating

Slot-bead coating permits the application of layers which may range from very thin to relatively thick, depending on the particular use. The application area extends from very slow coating speeds of a few cm/min up to medium speeds of 300-400m/min.
By means of slot-bead coating techniques, one (see figure 6) or more (see figure 7) fluid layers can be applied in a single pass onto the web which is to be coated; the number of layers is limited. In the slot-bead coating method, the fluid film leaves the exit slot of the coating die and directly bridges the very narrow bead gap between the die lip and the running web.
To achieve the most uniform possible film thickness on the substrate to be coated in cross-machine direction, the parallelism of the bead gap must be set with great precision as must the slot height. For this purpose, an essentially stable and highly accurate positioning system is required. For this application method, TSE develops and produces dies and also various accessory components which are used to optimize the application window.

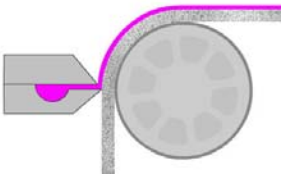

Figure 6

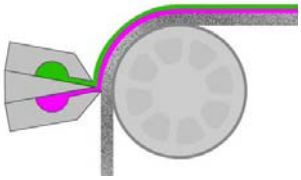

Figure 7

7. Liquid Preparation

The liquid preparation (see figure 8) takes a key role in premetered coating. Depending on the range of different liquids to be prepared and dosed, the selection of pump and degassing unit has to take in account the different behaviors of each liquid. The capacity range of the pumps has to cover the entire flow rates, while the operating window of the dosing pumps should not be utilized to its minimum or maximum. Hence the pumps should operate in the middle of its working ranges. Very high, as well as very low pump loads should be avoided and can lead to strips, pulsations or other unwanted effects in the coating. TSE can offer advice on the design of such liquid preparations or can offer entire systems with capable partners in this field.

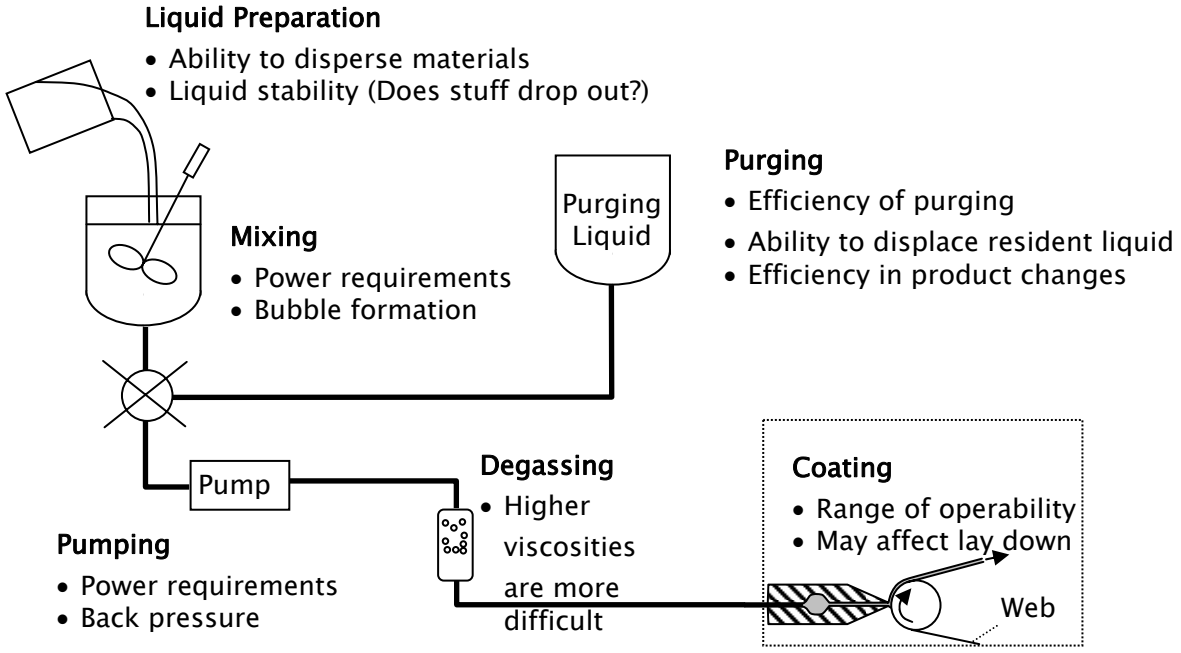

Figure 8

To avoid die distortions during operation, the temperature of the die as well as the entering liquid must be equal in small tolerances. A water circuit using tempering holes in the die keep the temperatures at constant levels. The liquid preparation must also be equipped with a temperature control system which is coupled with the system of the die in order to guarantee that both temperatures are equal. For some applications multi component liquids must be dosed. The premetered coating method allows the mixing in a static mixer located short before the entrance into the die. The varieties in the coating industry with different substrates and liquids are extremely wide. TSE has strong knowledge basis to cope with all different requirements.

8. Core Competence In Premetered Coating Systems

The dies of TSE Troller are of highest quality. Every die plate that is made at TSE is of excellent quality and polished to perfection. The accuracy and quality that you can expect when ordering from TSE are surpassed by no one. At TSE we use the most precise equipment for building, measuring (see figure 9), and testing our dies in order to be certain that we will produce equipment of the highest possible quality. This measuring device is accurate down to 0.1 microns (3.93701 microinches). Beside precision and surface quality, it is the design of the cavities that play a crucial role in achieving a good function and performance of the die. TSE has a wide knowledge in modeling different liquids and is in contact with leading institutes and universities in material science world-wide. Target of modeling the dual cavity distribution system is a uniform cross profile of the coated film on the substrate as well as long intervals between die cleaning cycles to achieve high coating line efficiency – for a wide range of applications of course.

Figure 9

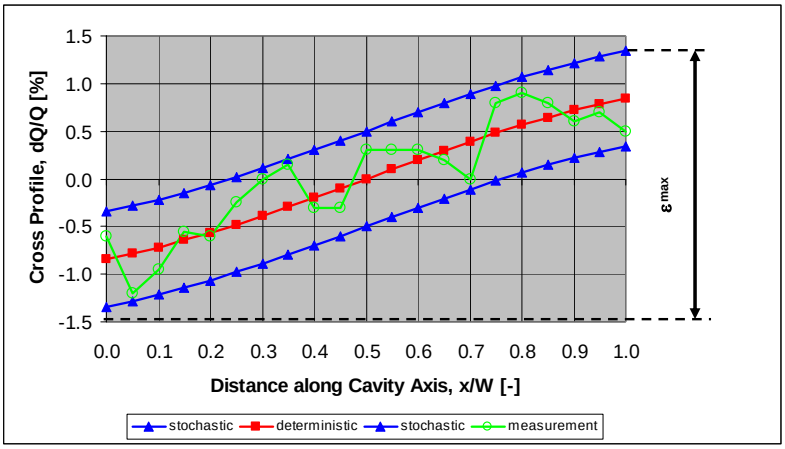

Figure 10

In the diagram (see figure 10) the uniformity of the film thickness is shown over the width of the die – measured from the feed port. For a center fed die the resulting profile will be symmetrical relative to the center line of the die. The red curve shows the theoretically calculated flow profile for a specific application. The blue curves represent the level of mechanical precision and the green line stands for the actual measurement data of the finished die.

9. High Precision Manufacturing

Depending on the requirements of the coating cross profile tolerances, TSE can manufacture dies in different precision levels defined in the following table.

Level of mechanical precision	Precision of nominal slot dept ±µm (±µ in)	Precision of inner slot surface (System 1) ±µm (±µ in)	Precision of outer slot surface (System 2) ±µm
B	20 (787.401)	6.00 (236.220)	6.00 (236.220)
A	10 (393.700)	4.00 (157.480)	2.50 (98.4251)
A with changeable lips	10 (393.700)	4.00 (157.480)	3.00 (118.110)
AA	5 (196.850)	2.00 (78.7401)	1.00 (39.370)
AAA	5 (196.850)	1.00 (39.370)	0.50 (19.685)
AAAA	5 (196.850)	0.50 (19.685)	0.25 (9.84251)

10. Know How About Fluid Dynamics

Maintaining optimum laminar flow conditions is crucial, especially for multi-layer applications, but as well for applications with particle loaded liquids and/or with reactive components. Vortices, as shown in figure 11, at the exit of an upwards orientated slot of a multi-layer slide die might create a recirculation inside the flow field. This could potentially mix both layers or lead to gathering, which would releasing particles and may lead to line defects.

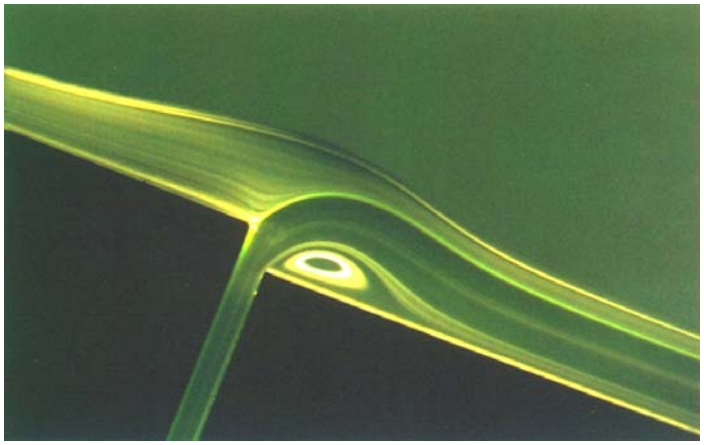

Figure 11 *(Photos courtesy by Dr. Peter M. Schweizer)*

By optimizing the geometry (see figure 12) of each detailed section in the different flow fields, they become less susceptible for disturbances and thus to defects of the coating, which lead to minor product quality.

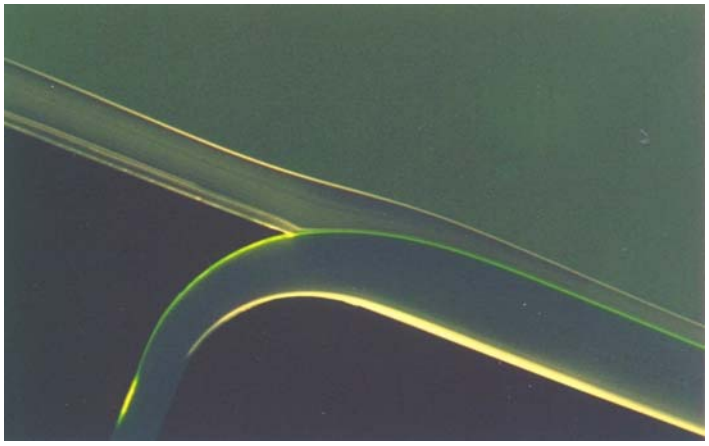

Figure 12 *(Photos courtesy by Dr. Peter M. Schweizer)*

11. Our Approach

TSE coating dies are especially designed to fulfill two different requirements, which are acting in an opposite direction.

The first is the uniformity of the coated film in cross-web direction. For the evenness in machine direction the uniformity of the web-run and of the metering pump are responsible – this can not be influenced by the applicator head.

The uniformity of the film thickness in cross direction depends on

- the design and on the mechanical precision of the die
- how the die is used during operation
- the operating conditions and mechanical precision of the coating process
- the uniformity of post-coating operations such as drying and curing

Focusing on the location of the slot exit, the cross profile depends on three classes of parameters, namely operating conditions, fluid properties and geometrical parameters. Especially, the measurement and definition of the rheological behavior is important. Very often real coating liquids show a shear-depending viscosity. Since the fluid experiences different shear rate levels the viscosity gradient must be known. For customers who do not have appropriate rheological measurement equipment, TSE can arrange access to laboratories who provide rheological measurement services.

The customers specific design of TSE dies covers a wide range of fluid properties and operating conditions. Therefore the distribution geometry in the "coat hanger" design is determined by optimizing more than ten parameters in accordance to one design product. With the geometry selected the other applications in the product range will be checked to determine the expected cross-web uniformity too. If some of the other products exceed the specifications the defined geometry will be tuned to improve the performance for these products, which usually is an iterative process. With this procedure the geometry fits to a fairly wide range of products and creates coated films with cross-web uniformities within tight limits.

The second requirement is to avoid internal contamination during a production campaign and to minimize the time needed for flushing and cleaning the die especially during change-over from one to another product. If a die has to be opened for cleaning this takes a long time which is not productive and increases the risk for damaging the die which would influence the quality of the coated film.

Ideally the distribution geometry is designed in a way that the die does not contaminate in production and so does not need intense cleaning at the end of a run. According to practical experience and theoretical considerations the wall shear stress is a useful measure for the tendency of a die to contaminate.

The optimized distribution geometry of TSE dies are designed such that no dead zones or spots with low wall-shear-stress are present. This minimizes contamination during coating and allows to flush the die with water or solvent. This also leads to a short residence time for all fluid elements inside the die which is important, especially when the coating liquids contain chemically reactive components.

Furthermore, TSE dies incorporate the possibility to alter the coating width.

12. Your Benefit

TSE coating dies combine superior quality of your coated products with minimized need for cleaning to help you economically produce products on a high level.

This leads to the following advantages for our customers:

- High efficiency with coating liquids and machinery
- Short return on investment (ROI) of equipment
- Less material consumption due to the high precision coating (cross web uniformity)
- Multilayer coating simultaneously (fewer runs)
- Wide range of applications
- Stable process, no adjustments
- Low number of defects
- Extendible
- Adjustable coating width
- Low maintenance (no wear parts)

If further explanations are needed do not hesitate to contact our office.

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