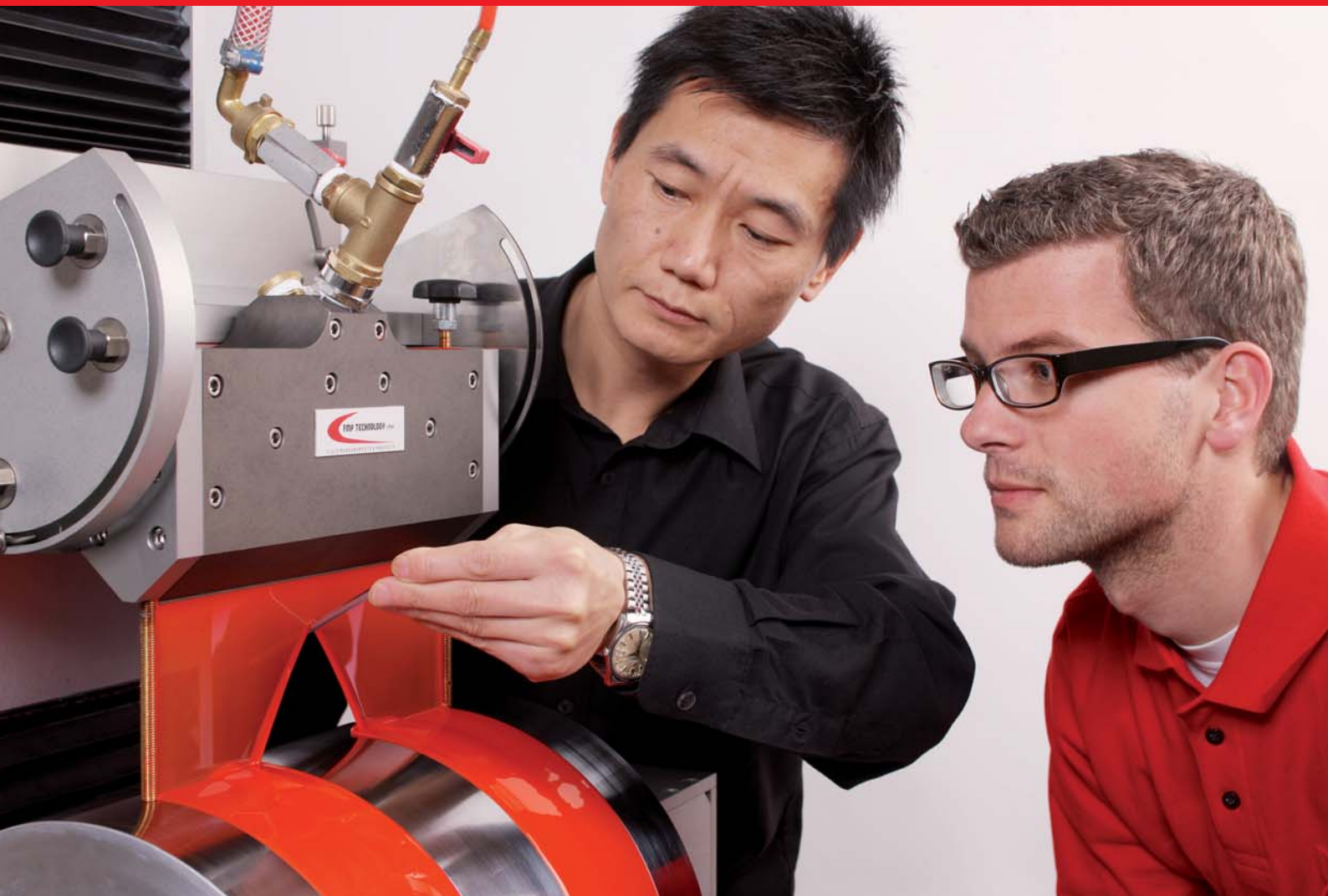




THE COATING WORLD OF FMP TECHNOLOGY GMBH





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The present brochure introduces the first business area from FMP TECHNOLOGY GMBH: Covering coating and drying techniques. The companies' specific know-how in this field are focused to customised research and engineering solutions for the coating industry that yield defect-free and reproducible coating results without time-consuming empirical experiments. The range of work contains theoretical computations of the overall coating and drying processes, verification experiments of numerical results on FMP laboratory coating devices and the manufacturing and delivery of innovative mass flow rate and viscosity independent coating dies. Some of the FMP-specialists is shown above.

COATING TECHNOLOGY A KEY COMPETENCE OF FMP TECHNOLOGY GMBH



Team of business area 1 of FMP TECHNOLOGY GMBH:
coating and drying technology



A selection of FMP products of coating and drying technology section

Defect-free coatings of substrates not only require reliable and easy-to-operate coating tools, such as **coating dies**, for example, but also impose demands on the solvents used. They must be bubble-free, for example. In addition, controlled **mixing processes** are necessary in order to ensure specific properties of the prepared coating fluids for flawless coats on substrates. In addition, the fluid supply to the coating tools being used must be **pulsation-free** in order to produce defect-free films on substrates. Hence it is the reproducible and controlled interaction of all the peripheral processes of a coating procedure that must be mastered in order to achieve film layers on substrates with high quality.

As a spin-off from the University of Erlangen-Nuremberg, FMP TECHNOLOGY GMBH was able to develop the fluid mechanics foundation for a theoretically based coating technology, initially during the course of university research. This yielded research results that made their way into innovative products for coating systems. All these patented products, such as coating dies, pulsation dampers, mixing processes, etc., make up the product range of FMP TECHNOLOGY GMBH today. The company's work is especially focused on different coating applications that yield defect-free coated, highly reproducible layers on substrates and without time-consuming, empirical preliminary tests.

Most of the research and development work, carried out jointly with customers, yield coating improvements of employed processes. This in return yields better coating and/or higher productivity, both making the moderate investments worthwhile.

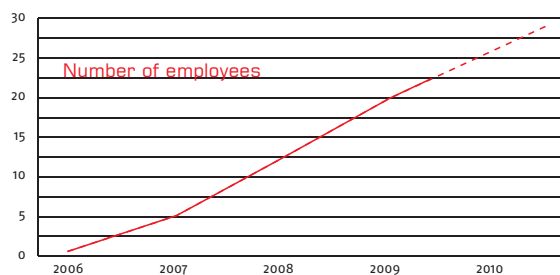
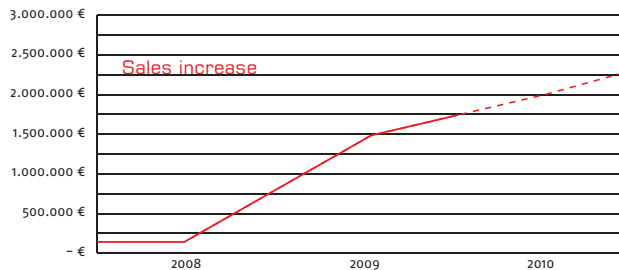
FMP TECHNOLOGY GMBH embraces today, altogether, four technology business areas, the first one covering coating and drying. The team that is active in this business area today is shown above. It consists of specialists in fluid mechanics, process engineering, design and measuring techniques as well as physics and chemistry.

„With this holistic process technology knowledge, we would like to show you how FMP TECHNOLOGY GMBH can be your forward-looking partner today and in the future for research and development, engineering and design, as well as for the implementation of innovative products for coating technology for your existing systems.“



Prof. Dr. Dr. h.c. Franz Durst
Founder & Managing Director of FMP TECHNOLOGY GMBH

UNIVERSITY ROOTS AS A SUCCESS FACTOR FOR INNOVATION AND TECHNOLOGY



- 1986** Establishment of the coating research group at the University of Erlangen-Nuremberg
- 2006** Founding of FMP TECHNOLOGY GMBH by the founders and Managing Directors Prof. F. Durst and M. Gillert
- 2008** Market launch of innovative, viscosity- and mass flow-independent coating dies
- 2009** Sales increase to € 1.5 million; number of employees grows to more than 20; expansion of the pilot plant to include additional test dies, sales of laboratory coating systems and measurement systems
- 2010** Further increases of products with a sales forecast € 2.0 million

At the beginning of the 1980's, Prof. F. Durst recognised the potential market for precision coating tools. After many years of research and development work and the registration of numerous patents, initially at the University of Erlangen-Nuremberg and later at FMP TECHNOLOGY GMBH, the production of easy to operate, innovative, viscosity- and mass flow-independent coating dies were finally mastered.

Since FMP TECHNOLOGY GMBH was founded by Prof. Franz Durst and Martin Gillert in 2006, it has been possible to support well-known companies involved in coating technology in providing specific research and development based solutions to problems. This began with first basic considerations for the introduction of new, modern and economical coating and drying methods. The early work was continued with the theoretical design of coating processes and practical verification of the results obtained on laboratory coating systems. The work continued right up to the manufacture and delivery of innovative FMP coating dies and entire coating systems.

Approximately 80 % of FMP employees work as graduated engineers, process technicians and physicists on the development, construction, manufacture and implementation of innovative products and solutions in the field of coating technology in order to make customer processes more efficient and economical. It was also possible to establish a wide-ranging network of external specialists at numerous locations for the manufacture of the actual product portfolio. A systematic and trusting dialogue exists between FMP developers and partners from industry, universities and institutions, each of whom generates the highest possible contribution to problem solutions in key fields of coating and drying. For the targeted enhancement and further development of its portfolio, FMP TECHNOLOGY GMBH establishes cooperative ventures and strategic alliances with knowledgeable partners.



„Our highly qualified engineers and innovative products help to meet reliably the quality demands forward by manufacturers and users of modern coating technology these days. Modern, numerical calculation methods ensure that reliable solutions can be provided without time-consuming empirical preliminary tests. Answers are given to whether a coating process, requested by a customer, is actually the best solution from technical and economic perspectives.“

Dipl.-Ing. Martin Gillert

Founder & Managing Director of FMP TECHNOLOGY GMBH

GENERAL INFORMATION



Architecture



Tapes, Paper, Carton



Silicon-Paper & Foil



RFID- μ -Chips

Various fields of coating where FMP TECHNOLOGY GMBH knowledge and products can be applied

INDUSTRY REFERENCES

FMP Technology GmbH supplies coating know-how and products as well as equipment for defect-free and economical coatings to different branches of industry. Customised coating tools are available, depending on quality requirements, which are implemented in close cooperation with users. In addition, in-house training provides customers with effective fluid mechanics knowledge, which is necessary for reliable and defect-free coating applications. This training can lie in different product fields since the applied approaches to coating are the same.



Sausage Skin



Wire & Yarn



Concrete slabs



Solar Cell

In addition, the annual two-day short course series on coating technology, always with changing focuses, is a good opportunity to learn about news from the world of the coating technology. These short courses are also supported by well-known, external lecturers from industry and academia.

The fields of coating differ, the methods and techniques are the same.



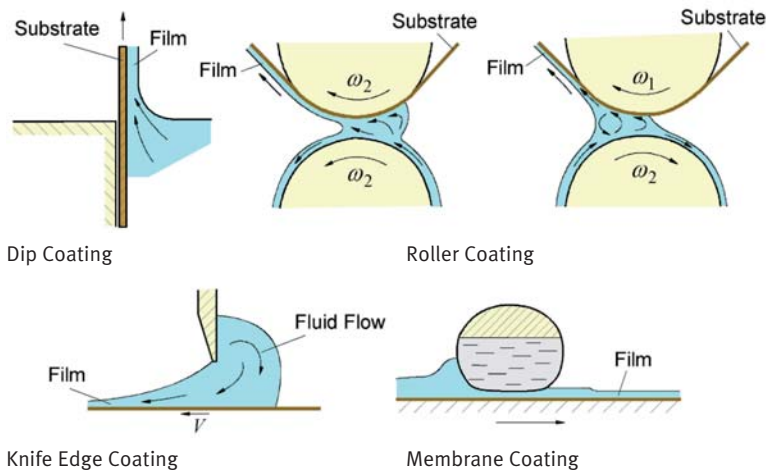
Short courses successfully held at the FMP TECHNOLOGY GMBH in the field of coating and drying.

CURRENT STATUS OF COATING TECHNOLOGY



SELF-METERED COATING PROCEDURES

A variety of methods are employed to apply thin layers of fluids onto base materials or packaged goods by current coating technologies using self-metered coating procedures. What characterizes the self-metered coating methods is that the attained wet film layer thickness is determined by the coating procedure and is not determined by the mass flow rate when operating the coating tool. The layer thickness on the substrate is relatively uncontrolled and determined by the methods shown on the left. The resultant film thickness strongly depends on the fluid properties, the chosen coating procedure and its freely selectable parameters, in addition to the coating velocity. The most important representative methods of this self-metered procedure are roller coating and knife edge coating, among others.



Self-metered coating methods for different applications

FMP TECHNOLOGY GMBH can support coating companies operating through theoretically based research and developments for all of the above shown techniques.

The precision of the applied layer thickness is essential for some substrates in the coating industry, especially for coatings with functional layers. Uncontrolled layer thickness variations, caused by changes in production conditions or in fluid properties, are no longer acceptable for many products. This is why so-called pre-metered coating procedures are increasingly used these days. With these the coated wet layer thickness is determined by the measured mass flow rate and the known substrate velocity U_w , (web velocity):

$$\dot{m} = \rho U_w h$$

where \dot{m} is the mass flow per metre of substrate width, ρ the fluid density, U_w the substrate velocity and h the height/thickness of the applied layer. The layer thickness h can be determined by the exact metering of \dot{m} (via pumps) and by measuring the substrate velocity. Hence, the desired layer thickness can be set with a narrow tolerance, regardless of other process parameters or properties of the coating fluid. Precision coating requires pre-metered coating techniques and coating dies that accurately provide the coating fluid.



CURRENT STATUS OF COATING TECHNOLOGY



PRE-METERED COATING PROCEDURES

It is obvious that the advantages of the pre-metered coating procedures can only be fully realized if, depending on the coating requirements, the accuracy of the cross-web distribution of the mass flow \dot{m} can be provided with high precision, i.e. with values of:

$$\frac{\Delta \dot{m}}{\dot{m}} \leq \pm 1 \% \text{ for precision dies}$$

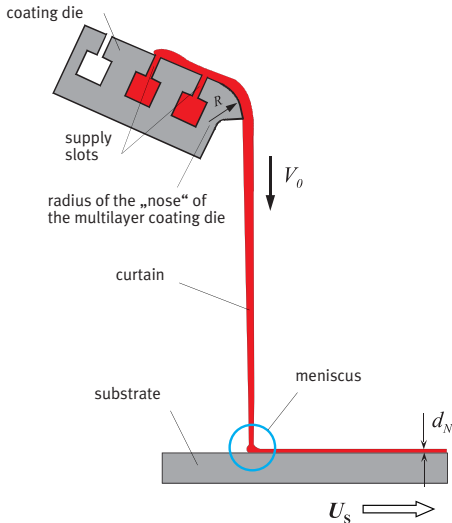
$$\frac{\Delta \dot{m}}{\dot{m}} \leq \pm 3 \% \text{ for quality dies}$$

$$\frac{\Delta \dot{m}}{\dot{m}} \leq \pm 5 \% \text{ for standard dies}$$

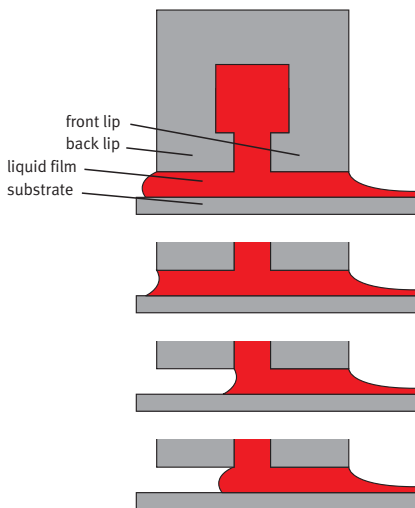
For pre-metered coatings, the required accuracies can be provided with conventional coating dies that are in use today, but only for one Reynolds number Re :

$$Re = \frac{\dot{m}}{\mu}$$

This means that the desired high cross-web distribution precision can be attained solely for one mass flow rate \dot{m} and one predefined fluid viscosity μ . Conventional dies "supply" cross-web distribution qualities of different precisions depending on the viscosity and mass flow rate of the coating fluid. Variations of more than 20 % are not uncommon for strong Re -number variations, with some of the dies used these days. Most existing dies operate very precisely only for one Re -number.



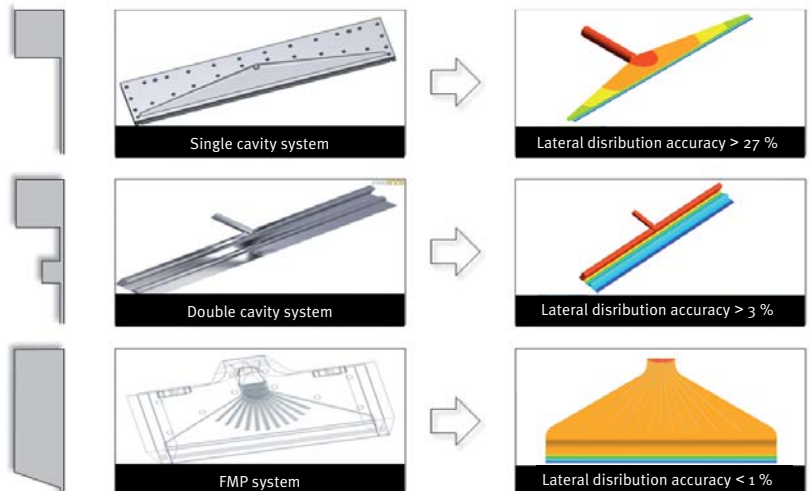
Functionality of curtain coating mode

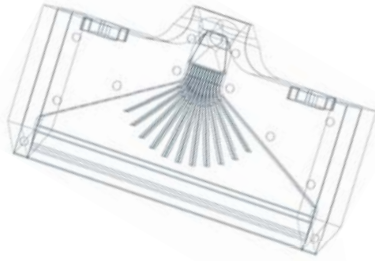


Functionality of bead coating mode

Hence, inaccuracies in the lateral (i.e. cross-web) distribution of the mass flow rate always have to be tolerated when using conventional coating dies. If the mass flow rate changes through a coating tool or if different fluid viscosities are used, the lateral distribution accuracy changes.

For coating, this inevitably means that in practice, investments must be made into multiple coating tools that are specifically designed for one mass flow or one fluid viscosity in order to avoid coating imperfections in the lateral distribution. With dies of this kind, the lateral height of the wet film layer thickness across the width of the substrate cannot be kept constant, when \dot{m} and μ are changed. The lateral distribution inaccuracy of conventional coating dies can ingenerally be more than 20 %.





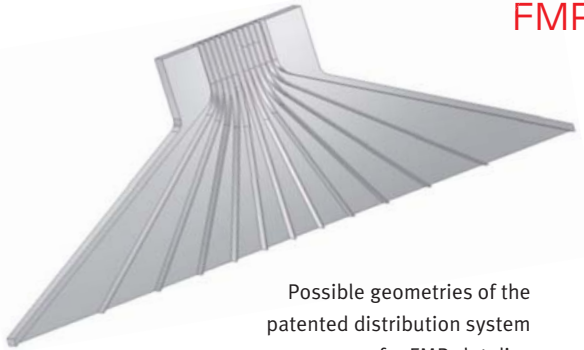
FMP PRODUCTS



THE PATENTED FMP DISTRIBUTOR

Due to the situation described above, regarding the accuracy of coating, FMP TECHNOLOGY GMBH conducted research and development work to create coating tools that do not lead to changes in the lateral distribution precision of the applied layer thicknesses, even for Reynolds number variations of 10^4 . These developments have been completed and have been patented. They resulted in FMP dies and FMP multilayer dies for pre-metered coating of wet films. These films have the same distribution precision of the applied layer for different μ - and \dot{m} -values.

The work resulted in an innovative distribution system that is used in the FMP coating dies. In contrast to conventional coating dies, the FMP distribution system achieves the lateral distribution precision not by pressure loss in the connection slots of distribution chambers or by a pressure loss in the "outlet slot" of a slot die, but by numerically designed channelling of the flow from the inlet to the area of the outlet slot. This is readily indicated by the distribution system shown below.

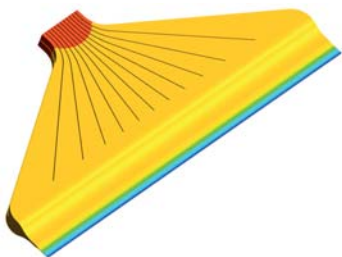


Possible geometries of the patented distribution system for FMP slot dies

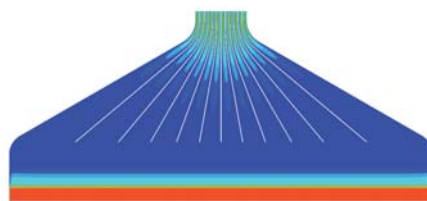
The patented distribution system consists of a fan-shaped insert that uniformly distributes the fluid coming from the inlet area over the entire width of the slot die. It has been possible to verify experimentally the very good numerical results. The computed pressure distribution, the velocity distribution and the distribution of the cross-sectional profile are shown below. To provide the coating fluid extremely even across the entire width of the die the Re -number can be varied over:

$$10^{-2} \leq Re \leq 10^2$$

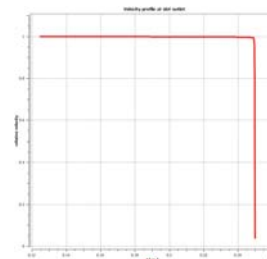
Verification experiments showed that very good results in the range of Reynolds-numbers of 10^{-2} to 10^2 can be attained. The display of the results which were obtained for $Re=0.01$ and $Re=100$ makes this clear.



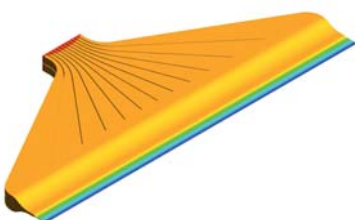
Pressure distribution ($Re=0.01$)



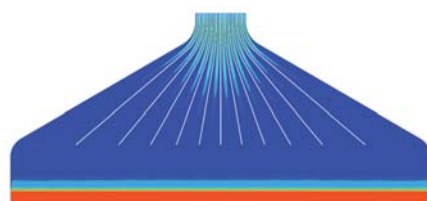
Velocity distribution ($Re=0.01$)



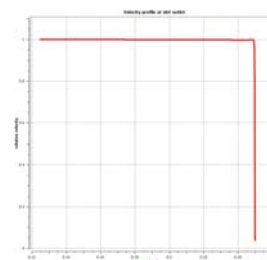
Velocity distribution ($Re=0.01$)



Pressure distribution ($Re=100$)



Velocity distribution ($Re=100$)



Velocity distribution ($Re=100$)





FMP PRODUCTS

INNOVATIVE SLOT DIES FOR ONE OR TWO LAYERS

In order to advance the operation of coating dies, i.e. to provide good lateral distribution precision for all practically relevant Re-values, FMP TECHNOLOGY GMBH conducted experiments that resulted in patented FMP slot dies. These show no longer an effect of fluid viscosity on the precision of the lateral distribution of the coated film thickness, at least for μ -variations between 1 and 10,000 mPas. A similar broad range of mass flow rate variations can also be used without having a negative effect on the wet film lateral distribution of thickness.

The state of the art regarding the dependence of the lateral distribution on the Reynolds number, i.e. the mass flow \dot{m} and the fluid viscosity μ , is generally known. However, the film thickness variations are undesired in many applications. In some coating applications mass flow and viscosity changes occur and have to be accepted several times each day. This is linked, with existing coating dies, to unavoidable variations in the lateral distribution precision of the coated film. The use of multiple coating tools is therefore necessary to ensure the desired lateral distribution precision for changing viscosities and mass flow rates. However, the application of several dies cannot be realised due to the associated high investment costs.

The FMP coating dies are modularly constructed in standard widths of 250, 500, 750 mm, etc., up to widths of more than 4 m. A similar series of 500, 1000, 1500 mm, etc. can also be provided. Due to the very general principle of operation, the new types of viscosity- and mass flow-independent FMP coating dies can be made in advance. Without any additional engineering work they can be delivered on demand without the long delivery times for coating dies that are typical in this industry, these days.

Customer-specific coating dies, that deviate from the standard lateral width slot-coaters, are also offered. These customised dies are optimised in terms of the coating width, the coating precision and the required fluid volume within the die or in terms of increased temperature demands (e.g. for the galvanisation of steel plates or for hot-melt coating). Additional numerical calculation methods and practical verification experiments are used for these optimisations.

The company also offer a special technique to vary the coating width of layers.



APPLICATION AREAS

- paper and cardboard industry
- photovoltaic industry (thin-film modules)
- imaging industry
- packaging systems
- film industry
- printed electronics (RFID microchips)
- adhesive tape industry
- medical products (plasters, latex bandages, indicators)
- construction industry (coatings of concrete slabs, construction wood, etc.)

APPLICATION METHODS

Due to the extensive process know-how in FMP TECHNOLOGY GMBH, it can be ensured that FMP dies can be used reliably in the following coating modes:

- bead coating mode
- curtain coating mode
- extrusion coating mode
- pre-metered roller coating mode

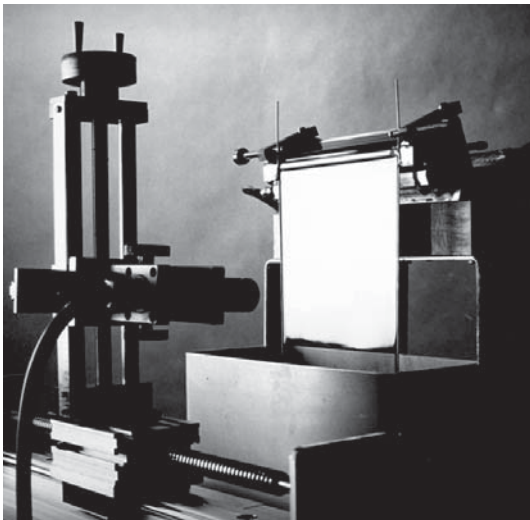
KEY FEATURES

- possible design as precision dies $\leq \pm 1\%$, as quality dies $\leq \pm 3\%$ or as standard dies $\leq \pm 5\%$
- guaranteed independence of the functionality dies from the fluid viscosity and mass flow
- changes of the coated width adjustment possible
- multilayer applications can be realised with slot (2-layer) and multilayer dies (2 – x-layers)
- lower investment than for conventional dies because engineering design work is no longer required for FMP dies with standard widths
- minimum delivery times, since FMP dies can be made without special layout due to the general operating principle of the dies
- FMP dies can be heated up to approx. 500°C for applications in the field of galvanising, hot melt, etc.
- Widths up to 4.000 mm are being targeted

FMP PRODUCTS

MULTILAYER DIES FOR SIMULTANEOUS COATING OF FILMS

The viscosity and mass flow rate independent fluid distributor of FMP TECHNOLOGY GMBH can also be successfully applied in multilayer dies. In this way multilayer dies arise with excellent lateral film thickness distribution. Multilayer dies with these properties are manufactured and delivered by FMP TECHNOLOGY GMBH.



The curtain coating mode of multilayer dies permits advantageously inline-coating of multilayer films on substrates that can move with very high velocities.

KEY FEATURES

- Depending on viscosity, coating velocities between 300 to 2.000 m/min are possible. Multilayers are, also at high velocities, simply coatable.
- Coating with bead coating mode is also possible with slide dies. This mode is practically unusual
- Guaranteed independence of the multilayer dies of fluid viscosity and mass flow rate
- Lateral distribution precision in the steps $\leq \pm 1 \%$, $\leq \pm 3 \%$, $\leq \pm 5 \%$

Multilayer-Die for coating in curtain coating mode and bead coating mode



LAUNDERS FOR COST-SENSITIVE PRODUCTIONS

The innovative launders, which FMP TECHNOLOGY GMBH has been able to develop, are being used increasingly in areas in which cost-effective coating tools have to be used, such as in the building industry, for coating concrete slabs, ceramic tiles, doors, window frames, furniture, etc.

Through theoretical calculations and practical field tests, FMP TECHNOLOGY GMBH has shown that curtain coatings are not just reserved for "high-precision applications", but can now be realised in the price-sensitive building sector through the use of simple launders.

The engineering know-how of FMP TECHNOLOGY GMBH is also advantageous using launders for the above mentioned fields.



Launder for coatings in curtain coating mode

KEY FEATURES

- guaranteed independence of the launder performance from the fluid viscosity and mass flow rate
- lateral distribution precision in graduations of $\leq \pm 5 \%$, $\leq \pm 10 \%$
- economical alternatives to realise coatings in curtain coating mode

FMP PRODUCTS



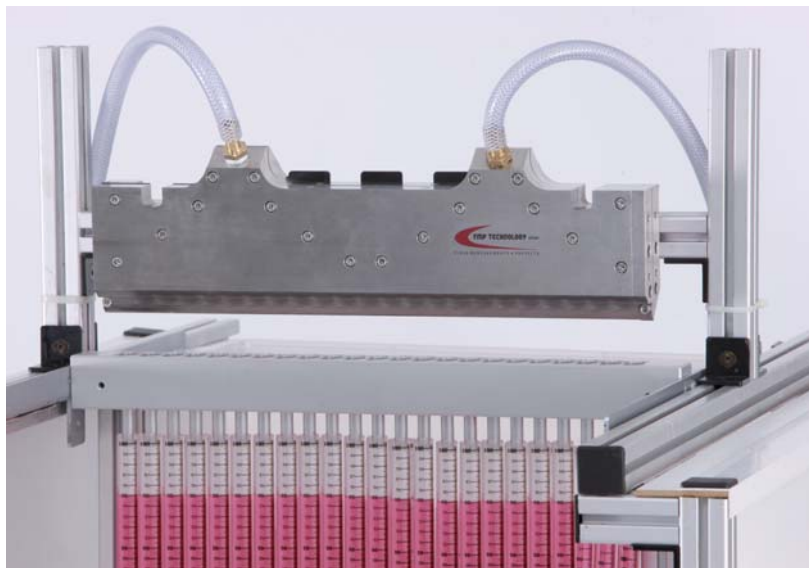
Cross-web distribution measurement system of FMP TECHNOLOGY GMBH

VERIFICATION AND ACCEPTANCE OF FMP COATING TOOLS

The manufacturing accuracies obtained by the productions of conventional dies are often not reflected in the actual fluid lateral layer thickness distributions which are ultimately decisive for the customer. The acceptance of performance by customers is usually based on measurements of manufacturing accuracies. To ensure performance accuracy, FMP TECHNOLOGY GMBH has taken a different path in order to provide proves that the FMP fluid lateral distribution precision, requested by the customer, is achieved. In addition to taking manufacturing tolerances into account, the lateral distribution of \dot{m} is additionally measured with special systems.

The employed measurement system results in an objective statement on the actual “performance” of a manufactured coating die.

FMP coating dies are always subjected to the above evaluation procedure to get the acceptance of the performance by the customer. FMP dies are considered as accepted only if the lateral distribution precision, requested by the customer, can be certified through measurements of the required local mass flow rates for different viscosities. The reproducibility is demonstrated to customers.



Cross-web distribution results of a FMP precision die, independent of the selected mass flow and fluid viscosity

FMP PRODUCTS

LABORATORY COATING SYSTEMS

■ Roller-Coating-Device

operated without substrates

The compatibility tests of coating fluids with a die, and also the verification of calculated coating windows, can easily be checked, without using a substrate, with a mobile test bench from FMP TECHNOLOGY GMBH. This device is indicated in the photograph below.

FMP TECHNOLOGY GMBH has successfully marketed roller coating systems in the photovoltaic industry, but with process-related modifications in order to realise coatings on substrates. Through its modular construction, the system can be used in a variety of ways, including the following coating modes of slot and slide coaters:

APPLICATION METHODS

- bead coating mode
- curtain coating mode
- extrusion coating mode

KEY FEATURES

- system allows the implementation of the calculated coating window and its extrapolation to large production systems
- substrate coatings (sample up to DIN A3) possible through system modifications
- working widths currently up to 250 mm
- speeds currently up to 300 m/min
- wet film thicknesses $\leq 5 \mu\text{m}$ possible
- lateral distribution precision of the wet film thickness $\leq \pm 1 \%$
- heatable roller and die application currently possible up to 120°C
- roller coating machine can also be operated with slide coaters
- knife edge coating is also possible

Hence the roller-coating-device of FMP TECHNOLOGY GMBH can be generally employed to the various coating methods.



Roller-Coating-Device without substrates;
coating on a roller

FMP PRODUCTS

LABORATORY COATING SYSTEMS

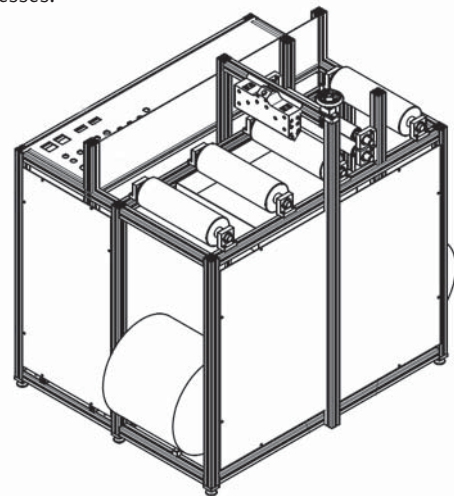
■ Roller-Coating-Devices coating with substrates

Coating systems are designed, manufactured, and marketed for experimental verification of the theoretically calculated coating windows. Different coating dies are installable.

The systems are characterised by controllable winding and unwinding, and are also modularly usable coating tools. Customised coatings on substrates can be carried out including pre-metered coating by means of FMP slot dies. Controlled knife edge coating is possible, right up to classical roller coating methods. Using optional switch-controlled porous medium burners, an extension can be added for substrate drying. On the other hand, cooling rollers can be integrated for applications in the hotmelt sector. Hence, the FMP laboratory coating systems can be effectively employed for developments of coating processes.



Roller-Coating-Device with a substrate track



3D-drawing of the laboratory

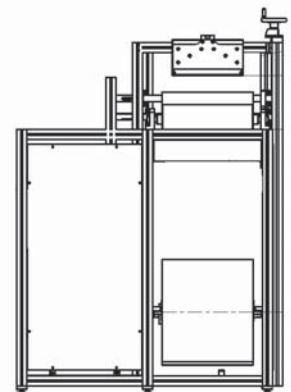
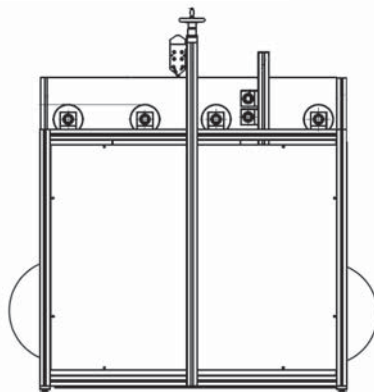
APPLICATION METHODS

Due to its modular construction, the laboratory coating system can be used in a variety of ways, including the following coating modes:

- bead coating mode
- curtain coating mode
- extrusion coating mode
- pre-metered roller coating mode
- knife edge coating mode

KEY FEATURES

- working widths of currently up to 500 mm
- speeds are provided currently up to 50 m/min



Experimental verifications on a laboratory scale coating system

FMP PRODUCTS

LABORATORY COATING SYSTEMS

■ Linear motor-driven system for “sample” coatings

The coating procedures and dies that FMP TECHNOLOGY GMBH developed are in increasing demand for automatically driven “sample” coating systems in the fields of paper-, textile-, metal-, foil-, etc. coatings. For these purposes, a laboratory system, driven by linear motors, was developed that allows coatings for almost any packaged goods with different surface qualities (paper, film, metal plates, cardboard, glass, textiles). Many coating requests from customers can be successfully satisfied by means of this lineary driven model coater. The system is also employed to develop coating fluids to ensure not only their chemical properties but also their coatability.

APPLICATION METHODS

Through the modular construction, the system can be used in a variety of ways, including the following coating modes:

- bead coating mode
- curtain coating mode
- pre-metered roller coating mode
- knife edge coating mode

KEY FEATURES

- working widths of currently up to 600 mm
- speeds are provided currently up to 300 m/min



Such systems have already been successfully used in the field of manufacturing cardboard and photovoltaic components.

FMP PRODUCTS

DEGASIFICATION SYSTEMS WITH COMPRESSED AIR APPLICATION

It is essential to degas the coating fluid before sending it to the coating die to be coated on a substrate to yield a high-quality fluid film. There is a great variety of degasification systems in use, operating on different principles. As conventional procedures have often not been developed specifically for degassing of coating fluids, they have serious disadvantages that must be eliminated through the provision of a degasification system that meets the requirements of the coating industry.

Henry's law suggests that degasification of a liquid can be achieved by lowering the pressure. In practice, degasification systems are used that work according to this principle. For this purpose, it is general practice to use vacuum pumps, pumping the air vapour mixture above the open surface of the fluid to be degassed. However, this means that not only the air but also the vapour of the fluid is pumped out. According to the laws of thermodynamics, however, the saturation pressure of the fluid must be reached above the surface of the fluid, so new fluid vapour is constantly released at the surface. This vaporisation is a very rapid process so that during the entire pumping time there are considerable losses of fluid from the coating fluid. This results in property changes of the fluid.

In contrast, the diffusion process that transports the air contained in the fluid to be degasified to the free surface is a very slow process. If no specific measures are taken, this leads to very long degasification times. Hence it is the fast vaporisation process of the fluid at the free surface and the slow diffusion process of the air through the fluid that require special measures to be taken during the application of low-pressure methods in the degasification of coating fluids. If this is not provided, then the properties of the coating fluid will change, for example, its viscosity, surface tension, etc.

With this background information, FMP TECHNOLOGY GMBH developed a degasification system especially for the coating technology that allows the degasification of coating fluids without changing the fluid properties such as viscosity, surface tension, and contact angle to the substrates. The FMP degasification systems can also be designed for very small or also very large quantities of fluids, depending on the application case. An analogous system could be made and used for the degasification of granulate materials during mixing and stirring.



Modifications to standard pressure tanks permit fluid degassing that is designed for the specific needs of the coating industry

KEY FEATURES

- Degasification of liquids is an important process for defect-free coatings.
- It is important that the degasification process does not induce changes to the properties of the fluid.
- The FMP degasification system takes into account the following physical foundations:
 - the solubility of solids increases with increasing temperature
 - the solubility of gases decreases with increasing temperature
 - the solubility of gases increases with increasing pressure
 - the solubility of gases decreases with the addition of solids
- When mixing coating fluids, stirrers are used. During the mixing process, the introduction of air must be avoided.
- The mixing process itself should take place with degasified fluids. If this is not possible, then the mixing system must provide measures for the degasification of liquids.
- It is important that the granulate that is added to a solvent is also degasified before it is added.



System for the degasification of solids when mixing and stirring

FMP PRODUCTS

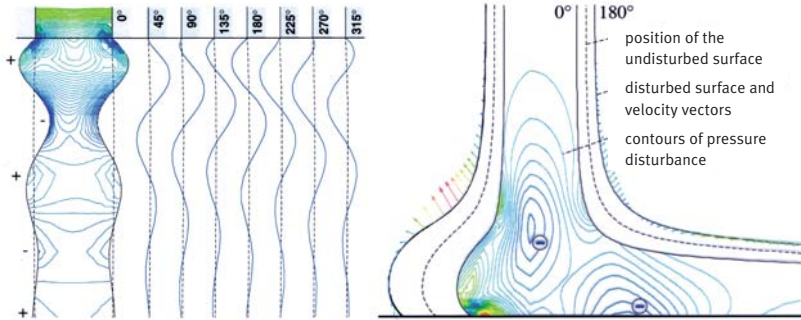


PRESSURE WAVE DAMPING

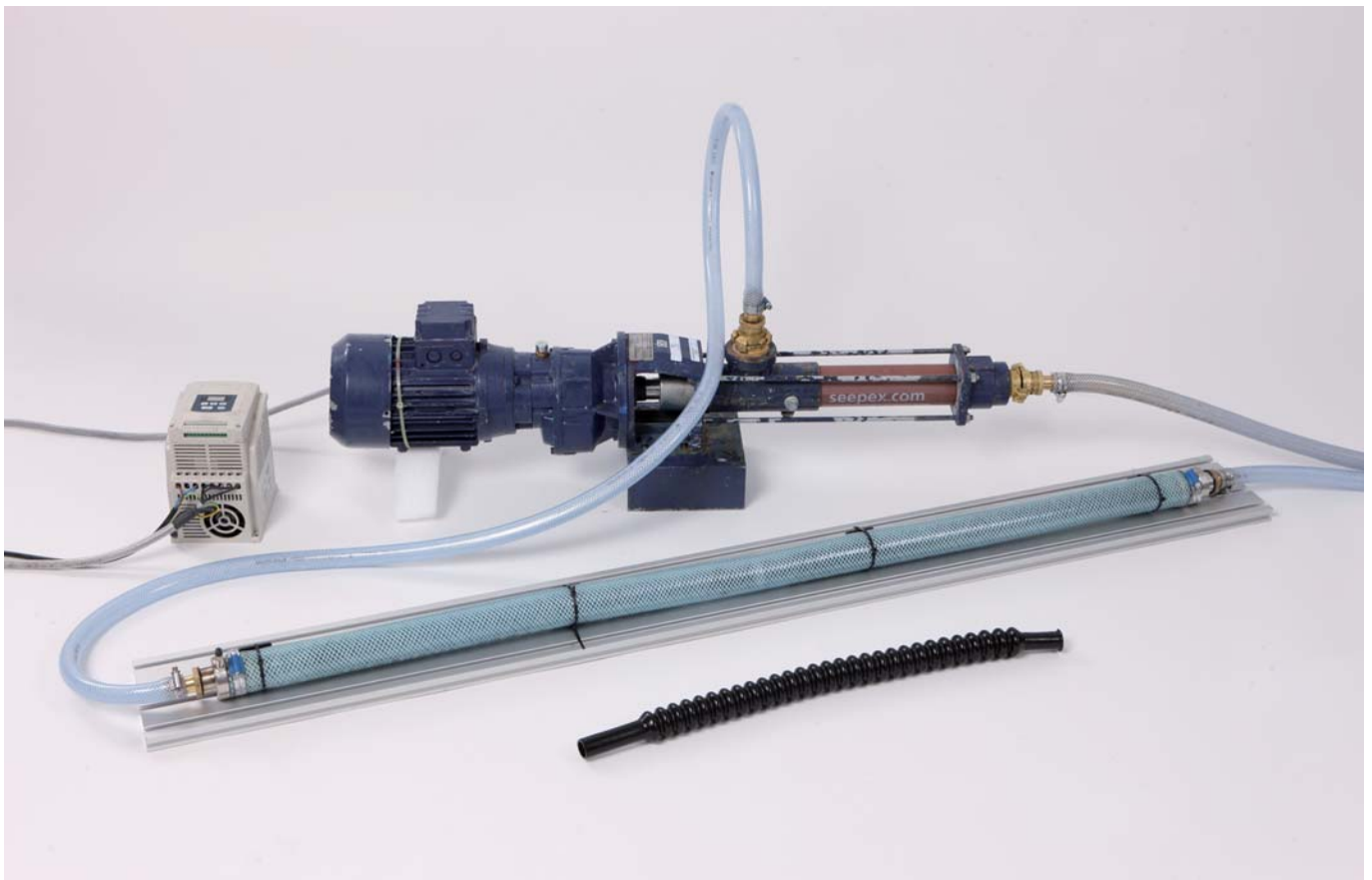
FMP pressure wave damping deals with the reduction, or mostly also the elimination, of pressure pulsations in piping systems that are introduced by the dosing pumps. These pulsations are usually introduced and, in certain frequency ranges, result in considerable, harmonic fluctuations of the mass flow rate.

In coating technology, “cross-bars” appear as faults of layers coated on substrates, i.e. the layer is laterally marked with sinusoidal changes to the layer thickness. A double hose system was developed by FMP TECHNOLOGY GMBH to eliminate this.

Pulsation damping systems of the kind shown below, that can be installed in a simple way, represent often the solution to eliminate defects of coated layers. Systems of this kind are offered by FMP TECHNOLOGY GMBH.



Pump-caused defects in coated layers are eliminated.



THE MOST IMPORTANT COATING PROCESSES WITH SLOT DIES



coating with slot-dies in bead coating mode



coating with slot-dies in curtain coating mode



coating with slot-dies in pre-metered roller coating mode

Different pre-metered coating processes in practice

In industrial coating processes, one or more layers of fluids are applied to substrates and then dried, so as to create solid layers on surfaces with specific properties. In order to coat layers on large substrates areas and to maintain a high precision, it is necessary to use the so-called pre-metered coating procedure. FMP TECHNOLOGY GMBH has specialized on pre-metered coating techniques.

A particular pre-metered coating process is selected for the use in industry, depending on the requirements of the material to be coated or the liquid film to be applied. Decisive in the choice are the required film thickness for the fluid to be applied, the necessary film quality and the necessary production rate to be able to carry out the coating with high productivity. Most often not the best coating process is chosen but the one with the best experience, in the respective coating method, that is available in a company. This last aspect often determines the continuity of the application of the coating method that was introduced into a company at an earlier time. Today it is still the experience with a specific coating process that decides on its employment rather than its principal benefits of quality and productivity.

The comparison of some of the main differences of the indicated coating processes points out that the outlined processes provide for film thickness variations by controlling the mass flow of the coating liquids. By applying a constant mass flow rate $\dot{m} = \rho U_w h B$ that is constant across the entire die width, the layer thickness h is clearly defined by the specified density ρ , the track velocity U_w and track width B . It is necessary to use specific coating tools in order to guarantee a uniform mass flow distribution across the entire width of a substrate to be coated.

This control possibility is often desirable for coatings, since the setting of a specific layer thickness can be controlled by a simple variation of the mass flow to the slot die.

Comparison of the principles of pre-metered coating processes

Bead coating mode

- Contact free coating method
- Thin wet film thicknesses are possible for velocities 0-400 m/min
- Low liquid viscosities are positive for high coating web velocities
- High liquid surface tensions are also positive for coatings in the bead coating mode

Curtain coating mode

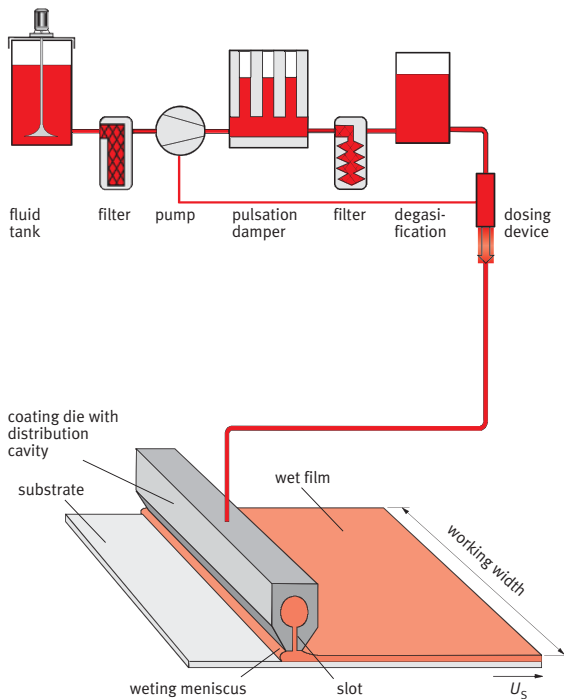
- Contact free coating method
- Thin wet film thicknesses are usually possible above 100 m/min
- Liquid surface tension is responsible for the stability of fluid curtain
- Low liquid surface tensions are also positive for coatings in curtain coating mode

Pre-metered roller coating mode

- Contact coating, which partially results in unintended structures
- Thin wet film thicknesses are possible between 0-600 m/min
- minimizing errors on fluid coatings concerning time-dependent variations of fluid rheology and complexity
- minimizing time for fluid changes and cost sensitive fluid losses

By presetting the fluid mass flow rate the wet film thickness can exactly be provided for all three coating methods!

THE MOST IMPORTANT COATING PROCESSES WITH SLOT DIES



Functionality of bead coating mode

APPLICATION AREAS

- paper industry
- cardboard finishing industry
- metal coating industry
- glass coating
- film manufacturing
- textile coating
- etc.

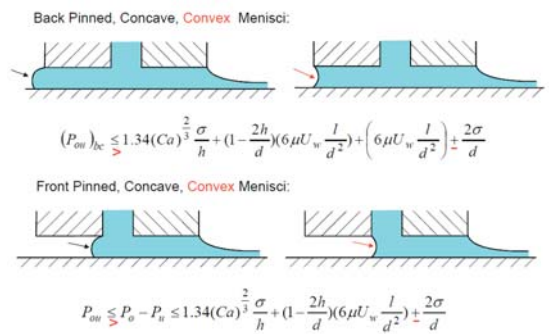
KEY FEATURES

- Low fluid viscosities result in high coating speeds.
- High fluid surface tension creates a wide coating window.
- Pressure differences between the front and back die lip are realised through the use of vacuum chambers and make it possible to have coatings in the entire maximum possible coating window.
- The distance between the die lips and the substrate must be more than double the film thickness so that good flow condition of the fluid under the lips is ensured. High geometric accuracy of the die, the coating system and the substrate is necessary.

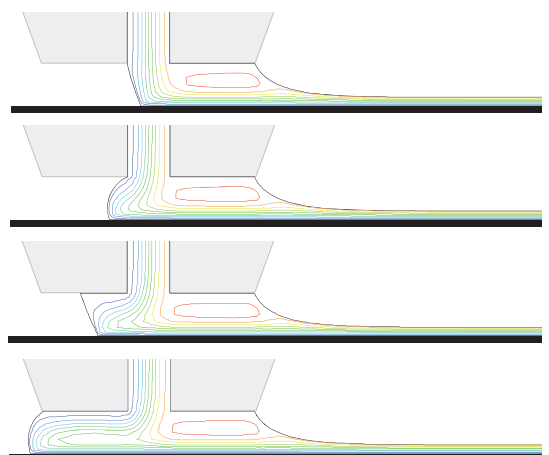
BEAD COATING MODE

Coatings in the bead coating mode are often used in industry to apply film thicknesses in the range 5–300 μm, where speeds from 0.3 to 5 m/s are common. If there are fluids with high viscosities the coating of thin films at high substrate velocities causes specific problems. By using low-pressure chambers in the back part of slot dies, instabilities can be controlled by changing the pressure level ($P_0 - P_U$) between the front and the back of the die lips.

The range of control for stable, reproducible coatings in the bead coating mode is very broad and can be achieved through just a few parameters, such as the applied sub-pressure, the fluid viscosity, the fluid's surface tension, the contact angle between the fluid and the substrate, the coating speed and the distance between the die lips and the substrate. The adjustment of all these parameters is often attempted, in practice, with substantial empirical work. It can be, however, easily performed with the use of the FMP software Coating Window Suite®. Knowing the coating window permits the coating parameter adjustment with easiness.



Pressure distribution below the slot die



Flow distribution below the slot die

THE MOST IMPORTANT COATING PROCESSES WITH SLOT DIES



CURTAIN COATING MODE

The curtain coating process is very advantageous, as it permits the application of thin layers at high substrate velocities. Depending on the fluid rheology, coatings at up to 2500 m/min are currently possible. Multiple layers are easy to apply, even at high substrate velocities.

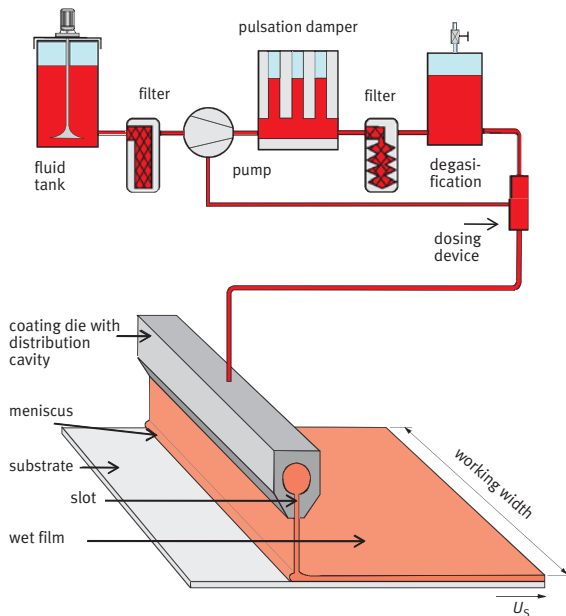
There is an increased demand for coatings in which multiple layers are applied simultaneously in an “inline process”. It is possible to make these multiple layers with special multilayer glide dies developed by FMP TECHNOLOGY GMBH. Analogous to FMP slot dies, the multilayer glide dies are also independent of fluid viscosity and mass flow and marketed in designs with the following precisions: distribution over the coating width for precision dies $\leq \pm 1\%$, quality dies $\leq \pm 3\%$ or standard dies $\leq \pm 5\%$.

The stability of a fluid curtain is ensured by the mass flow rate:

$$\dot{m} \geq \sqrt{2\rho\sigma b}$$

ρ = surface tension
 σ = fluid density
 b = slot thickness

Special film stabilizers are delivered by FMP TECHNOLOGY GMBH to avoid the addition of surfactances to coating liquids.



Functionality of curtain coating mode

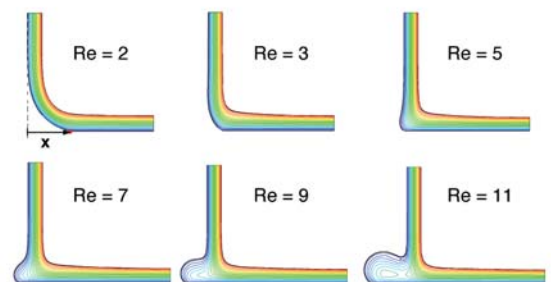
As for FMP slot dies, it is possible to produce multilayer glide dies from stainless steel, invar, aluminium, ceramic, etc., depending on the customers application and requirement.

APPLICATION AREAS

- paper industry
- film industry
- etc.

KEY FEATURES

- application of thin films at high web velocities with thin liquid films on the substrate
- possibility of multilayer applications
- coating of discontinuous substrates and uneven surfaces possible
- pre-metered process



Multilayer coatings in curtain coating mode

THE MOST IMPORTANT COATING PROCESSES WITH SLOT DIES



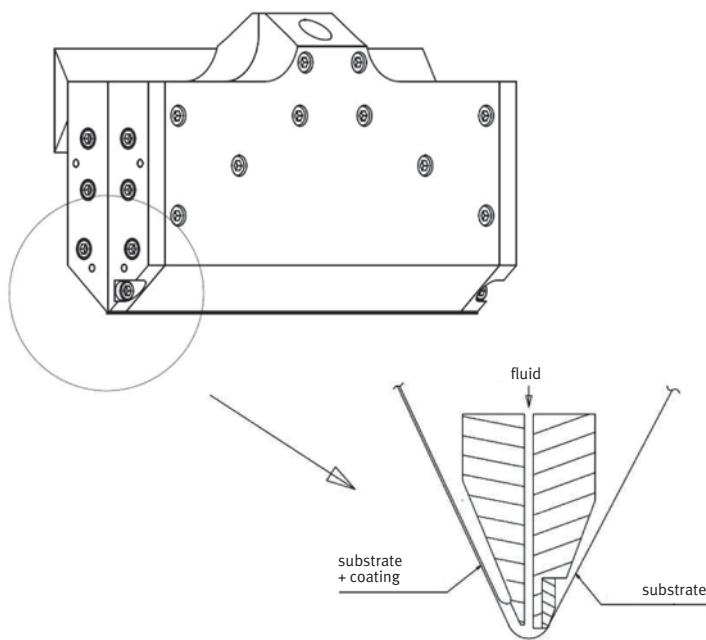
KNIFE EDGE COATING MODE

Flatness imperfection of the surface of substrates makes it practically impossible to use the slot die technology in the bead coating mode if very thin films are required, e.g. for film thicknesses of a few μm 's. The required distances between the uneven substrate and the bottom of the die lips are too small to permit large unevenness in the substrate. Thin layers on uneven substrate surfaces can only be applied at slow speeds. This general problem often occurs in the following industries and coating processes:

- paper industry
- cardboard finishing industry
- metal coating industry
- glass coating
- film manufacturing
- textile coating

As mentioned above, slot dies are difficult to be applied due to the uneven surfaces. For this reason, FMP TECHNOLOGY GMBH undertook more in-depth investigations in order to use slot dies in the knife edge coating mode (pre-metered knife edge coating procedure). It was possible to implement successfully the theoretical derivations and calculations of the associated coating window for this purpose.

In order to be able to obtain coatings in the knife edge coating mode, the reconstruction of the FMP slot die geometry was necessary. The back side of the die is nearly in contact with the substrate to be coated, at a distance of only a few micrometres. Due to the small gap that forms between the substrate and the back edge of the die, the fluid meniscus prevents the overflow of the fluid into the space behind the knife-edge system of the slot die. The necessary clearance is set through the control of the substrate pulling force and the inclination of the material. The equipment necessary for this mode of coating in a coating system must be taken into account.



FMP slot dies in knife edge coating mode

KEY FEATURES

- realisation of low to medium web velocities with uneven substrates
- high geometric precision of the die, good track guidance, etc. is necessary.



FMP slot die (500 mm)

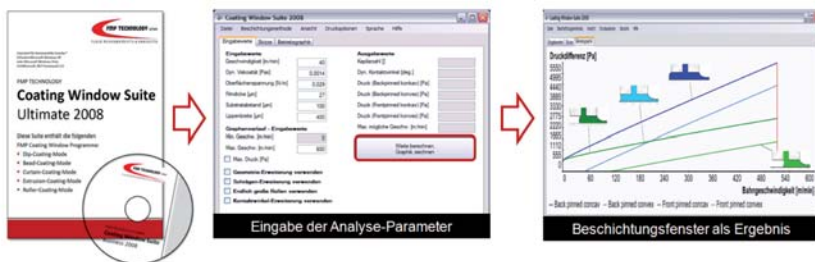
SUCCESSFUL INTRODUCTION OF COATINGS AT A GLANCE



Measurement of the surface tension and contact angle in the FMP TECHNOLOGY GMBH laboratory



Measurement device for the analysis of the fluid viscosity depending on the shear rate



FMP Coating Window Suite® software is currently available for the following coating modes:

KEY FEATURES

- dip coating mode
- knife edge coating mode
- bead coating mode
- curtain coating mode
- extrusion coating mode
- roller coating mode

FMP TECHNOLOGY GMBH has developed a general procedure for the efficient and targeted introduction of coating processes into industry. Regarding to the suitability of a particular coating for the customer's requirements of specific layers or products it has been used successfully many times. The procedure for this is generally the following:

FLUID STUDIES AND CALCULATION OF COATING WINDOWS

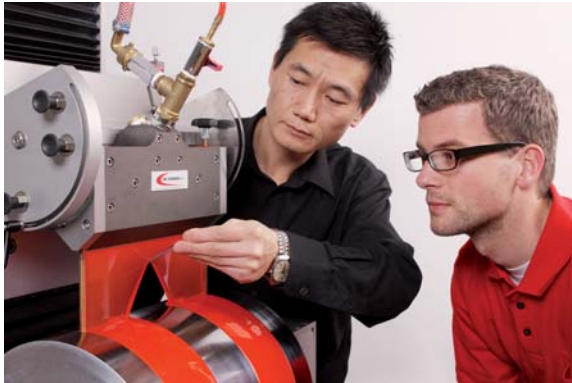
In the first step, the viscosity, surface tension, and contact angle of the fluid to the substrate are measured in order to use this information as a basis for coating window calculations. Coating windows represent the set of fluid properties and the coating parameters that ensure good coated films to exist. Outside of coating windows, defect-free coated films cannot be produced.

CALCULATION OF COATING WINDOWS

With the help of the **Coating Window Suite®** software, developed by FMP TECHNOLOGY GMBH specifically for the coating technology, coating windows for the different coating processes can be calculated on the basis of the fluid rheology measurement. Instead of using the conventional empirical approach, coating processes can be designed professionally, easily and quickly, taking into account complex boundary conditions.

Customers are often interested in the introduction of a new coating process in to their production lines. It is true that a qualitative assessment can be given for the feasibility of the different coating methods to assess the best application on the basis of general information. However, sound quantitative confirmation is only possible by using the Coating Windows Suite® software. Parameter studies provide a basis for the direct comparison of the different coating modes and then facilitate reliable statements on the optimum, targeted coating process.

SUCCESSFUL INTRODUCTION OF COATINGS AT A GLANCE



Coating verifications without a substrate track



Continuous flow studies by FMP TECHNOLOGY GMBH



Coating of substrates on a laboratory scale machine

VERIFICATION OF THE THEORETICALLY DETERMINED COATING WINDOW

In a second procedural step, tests show that the theoretically calculated coating window actually coincides with that in practice. This confirmation is generally not necessary; however it is usually requested by the customer to experimentally ensure the coating results. In addition, the experiments conducted with the coating dies show whether there will be unexpected difficulties in practice at the customer site with the coating fluid being used. For example agglomerations inside the die or chemical interactions between the fluid and the die material result from these investigations.

In order to determine whether, for example, the particles existing in metallic coatings will cause problems inside the die continuous, long time flow studies are conducted. The experimental equipment used for the application can be modified such that the die outflow can be operated within continuous test flows without exposure to the air. With two series of tests, that take 24 hours each, it is possible to determine the extent to which there are flow changes across the width of the die due to deposits of metallic particles.

Flow changes that result over time during the test are registered and their causes are determined. By opening the die, it is possible to determine the extent to which any occurring deposits are, in principle, natural or are caused by the selected die configuration. If the latter is the case, then customer-specific modifications of the dies can be developed if necessary. As that above, the tests are usually conducted for a period of 2x 24 hours in order to be able to yield concluding results that are relevant to practice.

VALIDATION OF SUBSTRATE COATINGS ON A LABORATORY SCALE

First substrate coatings can be carried out for customers with laboratory coating systems from FMP TECHNOLOGY GMBH. They are used to develop coating processes further but also to demonstrate that coating is basically possible with a specific fluid on a selected substrate. The objective of the FMP work is also to successfully and reliably introduce innovative, pre-metered and reproducible coating procedures using slot dies at the customer's site.

SUCCESSFUL INTRODUCTION OF COATINGS AT A GLANCE

MANUFACTURE OF PATENTED FMP SLOT DIES



Assembly of a 500 mm wide FMP precision die



The coating dies of FMP TECHNOLOGY GMBH are produced in different widths up to more than 4.000 mm. Coating dies with a multiple width of 250 mm (for example 500 mm, 750 mm, ... , 4.000 mm) can be produced cost efficiently without any additional engineering work and without long delivery times that are usually typical in the coating industry. This advantage is a breakthrough for the coating industry.

Customized coating dies with non-standard widths can be also produced due to customer's requirements concerning the specific installation situation, the required liquid width on the substrate, the fluid volume inside the coating die, etc. For these customized coating dies additional numerical computations and layout designs are needed and will be carried out through FMP-engineers.

If, after completion of positive theoretical and practical preliminary tests, it emerges that the optimum coating process suggests the application of a slot die, a patented viscosity- and mass flow-independent FMP coating die (in a standard width) can then be immediately approved for production without time-consuming design work. Customised widths are also available as so-called "customised dies", in which numerical calculation and design work are conducted, to ensure reliably the desired mode of operation.

Depending on the customer's application, precision dies $\leq \pm 1 \%$, quality dies $\pm 3 \%$ or standard dies $\leq \pm 5 \%$ can be delivered. The first preliminary performance test of the die, with verification of the required lateral distribution precision, takes place in our plant in Erlangen. When the die is delivered, it is put into service by FMP personnel, followed by intensive training for the operating staff of the customers, regarding handling and maintenance of the die. Additional components such as width adjustment of the coating or a low-pressure chamber to cover the entire coating window can also be delivered.

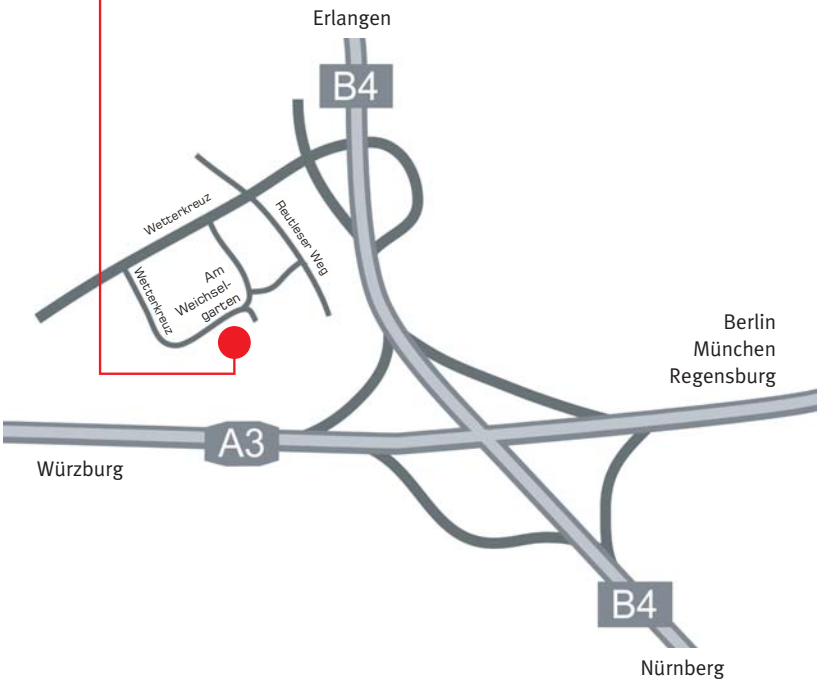
For optimum operation of coating dies, it is important that the peripheral components also work properly. FMP TECHNOLOGY GMBH is also happy to support its customers in the design of Coriolis mass flow measurement systems, pumps, pressure containers, mixing processes, degasification, anti-vibration platforms, etc. All this shows that FMP TECHNOLOGY GMBH is set to serve its customers with the best available knowledge in coating.





FMP TECHNOLOGY GMBH makes a claim to have leadership in several of the following key areas. FMP TECHNOLOGY GMBH ensures through theory based approaches that increasingly accurate theoretical design methods can be used to make reliable statements on the possible employment of innovative coating tools. This is made in the shortest possible time, creating a reliable foundation for investment decisions.

- Theoretical design of different coating processes
 - dip coating
 - roller coating
 - knife edge coating
 - spray coating
 - slot die coating and
 - multilayer film coating
- Experimental validation of theoretical calculation results on FMP laboratory systems
- Modernisation and improvements of existing coating systems
- Delivery of innovative, patented viscosity- and mass flow-independent coating dies
- Design and delivery of laboratory coating systems with different constructions for the different coating processes mentioned above



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Production | FMP TECHNOLOGY GMBH
Photography | Kurt Fuchs, www.fuchs-foto.de
Graphic design | lars kienle werbung, www.larskienle.de
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